BUILDING BRIDGES BETWEEN SCIENCE AND SOCIETY: NEW APPROACHES TO INCREASE PUBLIC UNDERSTANDING OF NUCLEAR TECHNOLOGY

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ABSTRACT

There is still great misinformation about the beneficial uses of radiation and the issue divides public opinion in Brazil and worldwide. Education and communication are crucial to increase public knowledge and understanding of the benefits of nuclear technology. Therefore, this paper presents two initiatives to reach teachers and students throughout Brazil, educating educators, combating misinformation and encouraging scientific and technological research. Taking advantage of the growing impact of Internet, the web-based educational project RadioAtividades (RadioActivities) aims the dissemination of nuclear technology contents for teachers and students of Elementary and Secondary Education. The content includes curiosities, interactive exercises and short courses that comprise the various aspects of the beneficial applications of nuclear technology. Furthermore, the website offers pedagogical support for teachers to enhance educators understanding of Nuclear Technology issues. The Nuclear Energy Museum of Federal University of Pernambuco is an educational initiative to teach nuclear energy applications in medicine, industry, agriculture and electric power generation. Moreover, the museum offers an interactive space that invites teachers and students to learn and search through exhibitions, interactive experiments, courses and participation in science fairs. Making use of modern educational concepts, the museum aims to improve public understanding of nuclear science, demystifying paradigms and prejudices and encouraging the development of critical thinking. These educational initiatives aim to provide trustworthy information, reaching children and teenagers, as well as their parents and teachers, who are most often unaware of the matter. Both projects have been carefully monitored, collecting important reference data about visitors' profile, suggesting new possibilities to approach society to nuclear technology.

RESUMEN

Aún hay una gran desinformación sobre las aplicaciones beneficiosas de la tecnología nuclear y el tema divide la opinión pública en Brasil y en el mundo. Educación y comunicación son cruciales para ampliar el conocimiento sobre el uso pacífico de las radiaciones, ya que la opinión pública se basa en información disponible sobre riesgos y beneficios. Este artículo presenta dos iniciativas que visan a alcanzar profesores y estudiantes en todo Brasil, educando educadores, combatiendo la desinformación e incentivando la investigación científica y tecnológica. Aprovechando el creciente impacto de internet, el proyecto RadioAtividades tiene por objetivo la diseminación del conocimiento en tecnología nuclear para profesores y alumnos de la enseñanza básica y media. El contenido incluye curiosidades, actividades interactivas y mini cursos, que engloban los diversos aspectos de las aplicaciones de la tecnología nuclear. El sitio ofrece apoyo pedagógico a los profesores, visando ampliar su compresión sobre el asunto. El Museo de Ciencias Nucleares de la Universidad Federal de Pernambuco es una iniciativa para la enseñanza de las aplicaciones de la tecnología nuclear en la medicina, industria, agricultura y generación de energía. El Museo ofrece un espacio interactivo que invita a alumnos y profesores a aprender por medio de exposiciones, experimentos, cursos y ferias de ciencia. Utilizándose de modernos conceptos educacionales, el Museo tiene como objetivo ampliar el conocimiento del público, desmitificando paradigmas y fomentando el desarrollo del pensamiento crítico. Estas iniciativas educacionales visan proporcionar información confiable que alcance a adultos y adolescentes, bien como a sus padres y profesores, que muchas veces desconocen el asunto. Ambos proyectos fueron ampliamente monitoreados, recolectando datos que pueden apuntar para nuevas posibilidades que contribuyan para aproximar la sociedad a la tecnología nuclear.

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1. INTRODUCTION

Nuclear technology helps to improve the lifestyle of our everyday life in much more ways than people can realize. Nevertheless, the issue divides public opinion in Brazil and worldwide. Public opinion is based on experience of the population with the available information about risks and benefits. In Information Society, where Internet is the most popular information source, most often social networks seem to associate radiation to nuclear weapons and nuclear accidents. The best known examples throughout history seem to be the big mushroom cloud in Hiroshima and Nagasaki, as well as major accidents such as Chernobyl and Fukushima.

According to some international surveys, the higher the education level, the more favorable are opinions towards nuclear power. The Globescan survey (2005) for the International Atomic Energy Agency (IAEA), published in 2005, analyses the results of public opinion conducted among a thousand adult respondents in each of the eighteen participant countries [01]. According to this report:

> *"Overall, men (33%) and people with high levels of education (36%) are more inclined than women (23%) and those with low levels of education (24%) to say that nuclear power is safe and that interested countries should build new nuclear power plants. People with less education (28%) are more likely than the well educated (21%) to say that nuclear power is dangerous and that all plants should be closed down."*

Eurobarometers are used to measure public opinion in Europe and overseas. Their report (2010), entitled Public Attitudes to Nuclear Power, was published in 2010 by the Nuclear Energy Agency (NEA) and the Organization for Economic Co-operation and Development (OECD). According to this document, "respondents with higher levels of education are more likely to think that the advantages of nuclear outweigh the risks". [02].

Nevertheless, another survey conducted by Globescan (2011) for BBC World Service following Fukushima crisis brings different trends: results suggest that opposition to nuclear energy grows in many countries and opposition to nuclear power has increased in 5 among 8 countries that were also polled by GlobeScan in 2005. The biggest impact was in Germany where 52% of the population supported the government's new policy of shutting all the nuclear energy facilities in the country [3]. The survey covered 23,231 citizens across 23 countries. In the Latin American countries that do not operate nuclear plants, opposition is well-marked. In Chile and Ecuador, respectively, 55% and 53% think that nuclear energy is dangerous and should not be used. In Panama and Peru, respectively, 38% and 30% think nuclear power generation should be abandoned in countries that have active plants. Brazil was one of the participating countries of this survey, even though only urban samples were used:

> *"In Brazil – which operates a few nuclear plants and was surveyed for the first time in 2011 – a plurality of 44 per cent of Brazilians says that their country should continue to use the nuclear power stations that are already in operation, but not build new ones. Thirty-five per cent say that nuclear power is dangerous and that all*

operating nuclear plants should be closed down as soon as possible – above the 12-country average (30%) – and only 16 per cent support the building of new nuclear plants – below the 12-country average (22%).”

Another survey, entitled “Brazilian Consumer Views on Food Irradiation”, conducted in 2009 [4], clearly demonstrates that misinformation and preconceived ideas impact heavily on the acceptance of irradiated food. The information given to participants about the benefits of irradiated food impacted positively. However participants generally still proved to be fearful about the risks and possible side effects. The research provided important data about factors which affect acceptance and purchase intention by the Brazilian consumer. In the published conclusions, the authors emphasize the importance of developing an educational program for Brazilian population, explaining the principles, purposes and benefits of food irradiation.

Therefore, this paper takes into account two main issues: (i) it is not a coincidence that more informed people favor nuclear technology, and (ii) it is a must to provide trustworthy information, reaching children and teenagers, as well as their parents and teachers, who are most often unaware of the matter. Education and communication are crucial to increase public knowledge and understanding of nuclear Technology peaceful applications.

2. BUILDING BRIDGES BETWEEN SCIENCE AND SOCIETY

Any construction depends on a solid foundation and education is the foundation of every society. Education transforms old prejudices and inspires new thoughts. This paper presents two educational initiatives to reach teachers and students throughout Brazil, educating educators, stimulating development and encouraging scientific and technological research.

The Nuclear Energy Museum is an educational initiative to teach nuclear energy applications in medicine, industry, agriculture and electric power generation. RadioAtividades Educational Portal is a web-based initiative to enhance knowledge on Nuclear Technology for children and adults throughout Brazil. Both initiatives, separately or together face the challenge to offer our society opportunities to improved nuclear science education.

2.1. The Nuclear Energy Museum of Federal University of Pernambuco

Sensitive to the fact that there is still great misinformation about nuclear technology among a large fraction of the population, the Nuclear Energy Museum is an initiative created to present the growing impact of the beneficial applications of radiations for individuals and society. The museum offers an interactive space which invites visitors to learn and search through exhibitions, interactive panels and experiments, transforming science education into a creative, interdisciplinary and relevant experience.

Making use of modern educational concepts, the Museum teaches the different nuclear energy applications, such as in medicine, industry, agriculture and electric power generation, among others. Visitors are introduced to nuclear technology history, as well as great scientists who have contributed to nuclear science, such as Albert Einstein and Marie Curie, among others. The Museum presents a wide range of nuclear techniques that contribute to improve our lifestyle, linking radiations and everyday life, making nuclear science education effective

and significant. Making use of models and interactive panels, children and adults understand each step of nuclear power generation, irradiation of gem stones, as well as the benefits of food irradiation. Moreover, the Museum presents nuclear medicine and the various applications of radioisotopes in medicine to diagnose, treat and prevent many diseases. Also, visitors learn about the basic elements of radiation protection, such as time, distance and shielding, as well as personal protective equipment, like masks and aprons. Yet, there are explanations about occupational radiation exposure monitoring and individual monitoring, and visitors are introduced to methods and instruments for radiation detection, such as radiation detectors and individual dosimeters.

In order to improve learning goals, this initiative tries to reach society, expanding its array of activities, such as public exhibitions in shopping centers and malls. Furthermore, the Museum affirms its mission educating educators and combating misinformation through summer courses, in order to promote dynamic engagement with teachers. The Summer Course is a program of the National Network of Education and Science, which involves universities and public schools, to improve science education throughout the country. Within a week, participants learn to develop new approaches between youth and science. From 26 to 30 January 2015, the course "Playing with the atom", held at the Nuclear Science Museum, received 17 participants.

2.2. Radioatividades: a web-based educational program

Taking advantage of the growing impact of Internet, the web-based educational project RadioAtividades (RadioActivities) is an iniciative to offer opportunities for students and teachers to learn and explore the puzzles of nuclear science throughout Brazil.

Internet access has increased strongly all over the country. The ICT Education 2011 survey [05], which comprehendeds interviews with 1.822 teachers, 606 directors of studies, 640 principals and 6 364 students brought the following report:

> *"The relationship between the frequency of activities carried out in pedagogical practices and the use of ICT suggests a challenge to incorporating technologies in education. There are signs that an increasing number of activities carried out in classrooms will create opportunities for the introduction of ICT in the teacher-student relationship. This is because ICT are used more often to carry out the least frequent activities proposed by teachers. Although there are limitations to the ICT infrastructure of Brazilian schools, the relationship between the most frequent activities and the use of these tools may be indicative that teachers are still struggling to change their teaching practices traditionally carried out without computers or the Internet.*
>
> *Students in turn, incorporate more naturally the use of computers and the Internet in their school activities. The indicator on activities carried out using ICT shows that 82% of the students do school research using computers and the Internet. Furthermore, 74% of them prepare theme projects using ICT, and more than half claim to use these tools for homework assignments (60%)."*

Regarding student access to the internet, this publication report several sample profiles. Age group results show that 40% of the interviewed students are up to 13 years old and that 14 to

15 year-old students represent 29% of the sample profile. When each region is studied separately, access to internet are led by Northeast and Southeast regions with a percentage of 34%, and 33% respectively, while South region represents 16%.The Center-West and North regions have the lowest average rate and together represent 17% of students access in Brazil. Among the predominantly activities involving the use of computers and the internet for school assignments in public schools, research activities stand in first place, with 82% of the total number of students in public schools. Overall, there is a higher incidence of computer and Internet use by teachers and students in private schools: "as well as in public teaching institutions, students in the private system also use ICTs in their school assignments, particularly for school research (96%).

The survey shows a comprehensive picture of ICT infrastructure in public and private schools, considering the relationship between the number of students per school and the number of computers in working condition. There are on average 20 operational computers in state or municipal institutions and approximately 500 students per school facility, according to the 2011 School Census. Even though 93% of Brazilian public schools companies claim to have access to Internet, 32% have connection speeds between 1 and 2 Mbps for the whole facility and a further 25% have speeds below that. Wireless connections are available in only 45% of the institutions. Among private schools, there is a higher incidence of computer and Internet, which increases use of ICT with students. Private institutions have on average 29 working computers, nine more than in public institutions, and count on fewer classes per grade and 4 to 5 fewer students per class.

Given these data, the challenge involved the ability to create an effective system, which pleases both children and youth. The website [06] counts on an original and creative design, created according to modern concepts, with different thematic roles which please both children and youth. The different themes are presented through curiosities, interactive activities and short courses. One of the most interesting ways to understand nuclear energy is the possibility to relate it to life itself. Therefore, in order to enrich the student's educational experience, encouraging a deeper learning, all topics are related to everyday life covering: radioactivity, electric power generation, transportation, protection, art, archeology, food irradiation and nuclear medicine, among others. All content can be easily accessed by any conventional internet point and there were created mobile apps, for IOS and Android Smartphones and tablets.

Moreover, this project provides pedagogical support for teachers, offering supplementary free course material for educators to develop in class. The content bank is designed to clarify and enhance teachers' understanding of core in Nuclear Technology issues, providing opportunities for teaching nuclear science through diverse perspectives, in a creative and interdisciplinary way.

3. DISCUSSION AND RESULTS

Both educational initiatives have been carefully monitored, collecting important reference data about visitors' profile.

From January 2010 to December 2014, the Nuclear Energy Museum received 16.080 visitors, among which 84 foreign visitors, as seen in FIGURE 1. Further than the 13.968 visitors from the state of Pernambuco, the museum received visitors from 14 other Brazilian states, as seen in FIGURE 2. Furthermore, in order to improve the actions toward society, visitors are invited to rate their experience at the Nuclear Science Museum, on a 10-point scale, where 10 means a great experience. Among 1.442 responders, the largest percentage of those surveyed, which means 88,6% of the responders, rated 9 to 10, proving the high quality experience in learning nuclear science at the Museum, as seen in FIGURE 3.

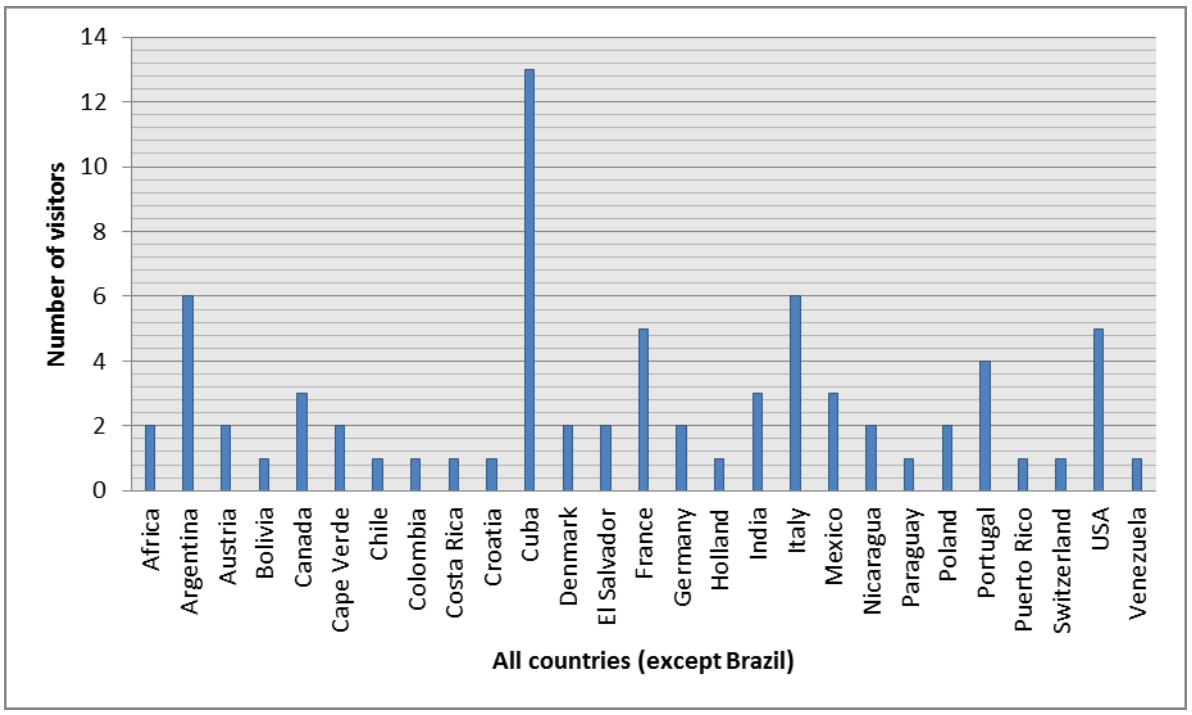

Fig 1. Visitors from all countries except Brazil

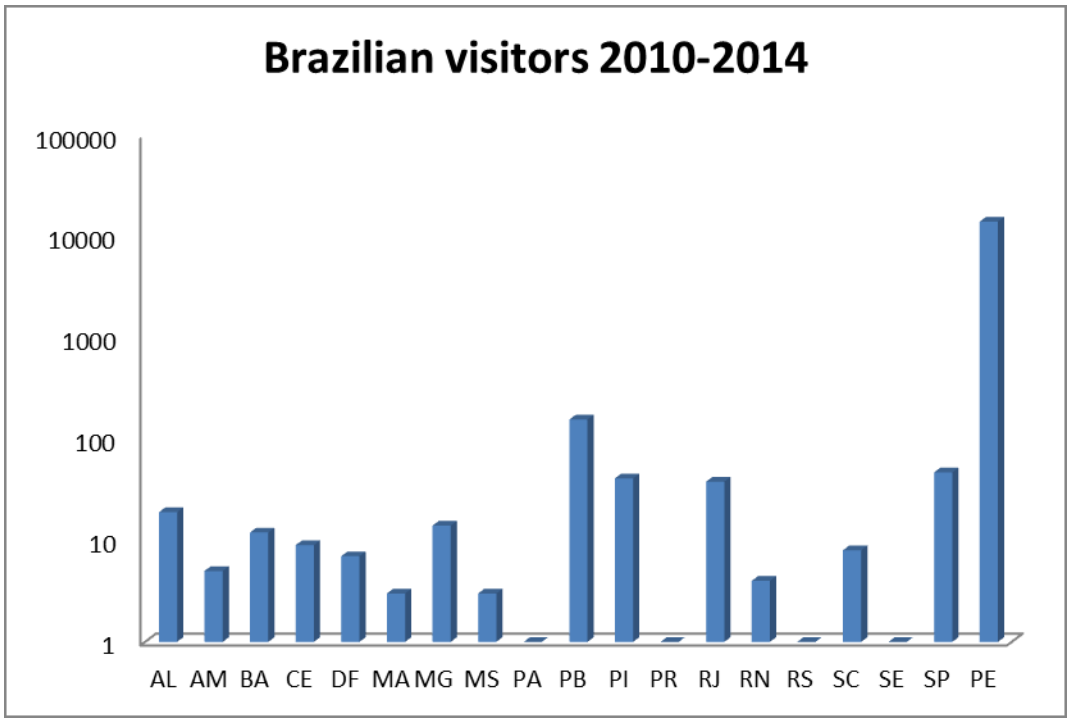

Figure 2. Brazilian visitors per state

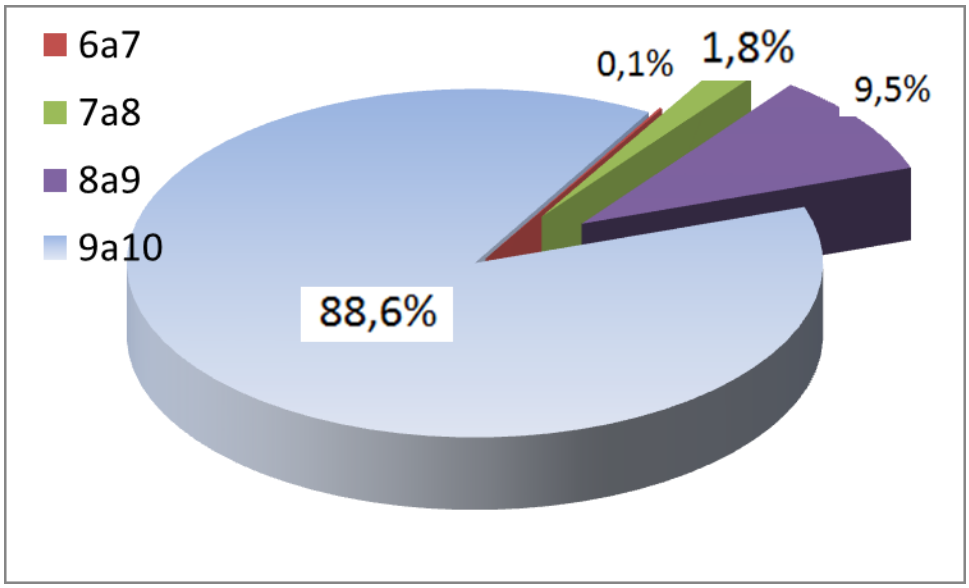

Figure 3. Visitors`response rates from 2010 to 2014

Radioatividades Educational Portal was first implemented in a web environment in July 2014 as a pilot project. Taking into account this is a pioneer project with the prospect of long-term use, the challenge involved the combination of multiple computer technologies that allows a robust, effective, and flexible system, which can be easily adapted according to future technological innovations. The project counts on two integrated modules: the website and a Learning Management System (LMS).

Google Analythics was used to the investigation of the website usage profile between 01/08/2014 and 30/07/2015. Even though the website was visited from many other countries during this period, this paper focus on Brazilian users. According to Analythics monitoring reports, the site Radioatividades counted on 745 visits from Brazilian users, among which 298 were returning visitors. The states of Rio de Janeiro and São Paulo lead the access to the website, respectively with 314 and 308 visits. TABLE 1 brings the results by trimester. Google Analythics reports information about users operational systems profiles, services providers and screen resolutions, collecting fundamental information for strategical planning of the evolution of this Project, as the WEB platform tools and functionalities must be developed according to our target public needs, regarding new possibilities of media, mobile access, feeds of content and information sharing. Even though, the given data refers only to website pages and curiosities, and do not include short courses and interactive activities.

Table 1. Google Analythics reports from 01/08/2014 to 30/07/2015

	Sessions	State of São Paulo	State of Rio de Janeiro	Other states	New visitors
01/08/2014 to 31/10/2014	320	114	176	30	198
01/11/2014 to 31/01/2015	168	51	106	11	87
01/02/2015 to 30/04/2015	110	63	16	31	65
01/05/2014 to 31/07/2014	147	80	16	51	97

Short courses and interactive activities run in an external ambience. Due to the fact that the target public is made up of children and teenagers who usually are not allowed to fill in forms with personal data, there are no inscriptions asked to enter the LMS. To face the great challenge of monitoring LMS data without inscriptions, there was created a customized LMS in June 2015, which permits a tracking system to follow computers IPs. The tool brings detailed data, such as how many courses or activities each user accesses and concludes. From august 2015 on it will be possible to track these two independent systems interrelating information. The possibility to cross information will bring a new perception of users' habits and enable important data to suggest new possibilities for the development of the system.

4. CONCLUSIONS

There is still great misinformation about nuclear technology and its beneficial uses of radiation. Public opinion is strongly affected by the media and social networks, which not rarely associate radiation to nuclear weapons or major accidents. Overall, people seem to be fearful about the use of radiation and its harmful effects on human health. Most likely the public opinion would be different if the authorities took more time to invest in individual education of the population, especially in the education of young people.

According to several international entities surveys, more informed people favor nuclear technology. Taking into account that education is the foundation of every society, these two educational projects intend to present the beneficial uses of radiation in different contexts, such as medicine, agriculture, industry and electric power generation, proving nuclear technology as part of our everyday life and a must to improve the quality of our lifestyle in many more ways than people can realize. Education transforms old prejudices and inspires new thoughts, stimulating development and encouraging scientific and technological research. Our goal is to promote the benefits of nuclear technology for new generations, combating misinformation in our society, omission of the media and knowledge fragmentation.

5. REFERENCES

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