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# The Nuclear Energy Museum in Brazil: Creative Solutions to Transform Science Education into Meaningful Learning

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***Abstract*—**Nuclear technology is a controversial issue among a great share of the Brazilian population. Misinformation and common wrong beliefs confuse public's perceptions and the scientific community is expected to offer a wider perspective on the benefits and risks resulting from ionizing radiation in everyday life. Attentive to the need of new approaches between science and society, the Nuclear Energy Museum, in northeast Brazil, is an initiative created to communicate the growing impact of the beneficial applications of nuclear technology in medicine, industry, agriculture and electric power generation. Providing accessible scientific information, the museum offers a rich learning environment, making use of different educational strategies, such as films, interactive panels and multimedia learning tools, which not only increase the enjoyment of visitors, but also maximize their learning potential. Developed according to modern active learning instructional strategies, multimedia materials are designed to present the increasingly role of nuclear science in modern life, transforming science education into a meaningful learning experience. In year 2016, nine different interactive computer-based activities were developed, presenting curiosities about ionizing radiation in different landmarks around the world, such as radiocarbon dating works in Egypt, nuclear power generation in France and X-radiography of famous paintings in Italy. Feedback surveys have reported a high level of visitors' satisfaction, proving the high quality experience in learning nuclear science at the museum. The Nuclear Energy Museum is the first and, up to the present time, the only permanent museum in Brazil devoted entirely to nuclear science.

***Keywords*—**Nuclear technology, multimedia learning tools, science museum, society and education.

## I. Introduction

THERE is still great deal of misinformation about nuclear science among the Brazilian population and the scientific community is expected offer society a wider perspective of the issue. This paper presents the Nuclear Energy Museum, an initiative to teach nuclear energy applications in medicine, industry, agriculture and electric power generation.

The use of modern educational concepts and practices, contribute to collective knowledge building, enabling critical thinking, demystifying paradigms, improving the general public's understanding of nuclear science. The Nuclear Energy Museum affirms its mission informing new generations, educating educators, and transforming science education into meaningful learning.

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## II. Engaging Science and Society

### *A. Building Bridges between Science and Society*

The Nuclear Energy Museum was created to teach the general public about the different perspectives of nuclear technology's beneficial applications in modern society. The museum counts on several interactive spaces which enable visitors to learn and explore the nuclear puzzles through experiments, exhibitions and interactive panels, transforming science education into an attractive, interdisciplinary and significant experience [1].

Taking advantage of a range of educational strategies, the Nuclear Energy Museum presents the different nuclear energy applications, such as in agriculture, medicine, industry and electric power generation. Visitors are invited to hear about the history of the technology and the well-known scientists who have contributed to nuclear science, such as Wilhelm Roentgen, John Dalton, Albert Einstein and Marie Curie [1].

Linking radiation and everyday life, the museum proposes a global perspective of nuclear techniques that contribute to improving our lifestyle, making nuclear science education relevant and meaningful. Through interactive panels, visitors see each step of nuclear power generation, as seen in Fig. 1. Moreover, visitors learn about occupational radiation exposure and basic elements of radiation protection, shielding, protective equipment and dosimeters. Among the many beneficial applications of nuclear science, the museum presents the important role of nuclear medicine to diagnose, treat and prevent diseases. Teachers and students learn about the most commonly used radioisotopes and their contributions to the field of nuclear medicine, as seen in Fig. 2.

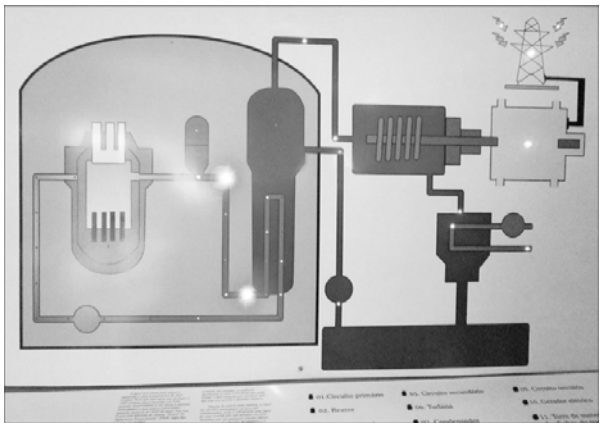

Fig. 1 Interactive panel to explain electric power generation


Fig. 2 Interactive panel and material used to explain nuclear medicine

Expanding its array of activities far beyond the geographic frontiers of the museum in order to build new bridges between nuclear science and society, the museum team promotes public exhibitions in shopping centers, as well as summer courses. The Summer Course is a programme of the Brazilian National Network of Education and Science to enhance science education throughout Brazil. In a one-week-course, participators experience new approaches to teach and learn science. In January 2015, 17 teachers attended the training course "Playing with the atom", offered by the Nuclear Science Museum [1].

### *B. Linking Science to Everyday Life*

In order to incentivize the passion for learning nuclear science, the museum presents each year new interactive learning materials, developed according to the most modern educational concepts.

In May 2016, under the theme "Revealing the radiation secrets behind the most beautiful cultural landmarks", students and teachers were invited to improve their knowledge in nuclear science through lectures and a rich amount of web-based interactive educational activities. Interactive multimedia teaching materials capture children's attention and improve the students' learning motivation.

A range of fun interactive learning activities for kids and adolescents were created presenting different aspects of radiation through some of the world's magnificent landmarks which live in popular imagination, as listed below.

- Giza, in Egypt: archeological monuments and the use of carbon-14 for radiocarbon dating works.
- London, in England: museums' treasures and the use of X-ray computed tomography (X-ray CT) for imaging the contents of sarcophagi and Egyptian mummies.
- Florence, in Italy: the use of X-radiography to reveal artists' working process, composition of materials and painting techniques.
- Paris, in France: nuclear power generation to illuminate Paris, "The City of Light".
- New York, in the United States of America: The Grand Central Station and the naturally occurring background radiation.
- La Paz, in Bolivia: the intensity of cosmic radiation that reaches the planet Earth.

Aside from foreign destinations around the world, some interactive activities were developed demonstrating radioactivity issues in famous touristic destinations in Brazil, as well.

- State of Espírito Santo, in Brazil: monazite sand in Guarapari Beach, a coastal town that attracts thousands of tourists every year.
- State of Minas Gerais: areas of high natural radioactivity in Poços de Caldas, best known for its thermal baths and several resorts.
- State of Rio de Janeiro: nuclear electric power generation and its benefits in one of the most visited states in the Southern Brazil.

## III. Interactive Multimedia Material

### *A. Transforming Science into Meaningful Learning*

Pedagogical Strategies in Instructional Design were developed according to the best methodological and educational methods regarding the target public. Learning activities make use of several multimedia resources, such as slideshows, animations and interactive exercises.

One of the most interesting ways to learning science is focus on meaningful learning. According to Ausubel's meaningful learning theory, in which learning is meaningful whenever it can be related in a non-arbitrary way to previous knowledge. Meaningful learning involves subsumption, a process where new information is linked to relevant preexisting structure, modifying the newly acquired information, as well as the preexisting aspects of the cognitive structure [2].

As a matter of fact, meaningful learning should not only apply to students and young visitors, but also to teachers and parents who, most often, have little or incomplete knowledge about nuclear sciences. In this sense, Malcolm Shepherd Knowles, a well-known American educator, puts adult education at the heart of the learning process [3]. According to Knowles, educational solutions development must take into account four principles: experience, readiness to learn, orientation to learning and motivation to learn. There should be given the opportunity to use their existing knowledge and the great deal of life experience they bring. It is important to consider that adults are more interested in subjects that have practical application to everyday life. Knowles (1975, p. 18) believes that adults are motivated by internal incentives and privilege self-directed learning, in which:

> *"...individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes."* [4].

In an Information Society where digital media are part of everyone's everyday life, multimedia-based resources might

facilitate disposition to learn, creating opportunities for substantive and meaningful knowledge. The use of non-formal interactive environments and ludic tasks based on scientific material can be a powerful learning tool for children and adults [5]. Nevertheless, effective instructional design strategies must be taken into account.

Instruction design implies identifying the learning needs of the audience and the learning goals for action. Instruction design includes planning, implementation, evaluation and future instructional references [6].

Regarding these issues, nine interactive educational activities were developed for the Nuclear Energy Museum. Children and adults are offered meaningful learning experiences through a variety of amazing, different perspectives on some of the world's most famous landmarks. All activities are based on multimedia self-instructional material. The ludic components and exercises were designed to produce engagement and stimulate curiosity, leading the public to further questions and reflections.

Other than effective media teaching strategies, the development of these interactive activities took into account multiple technological aspects, regarding current challenges and future opportunities.

### *B. Technological Issues: Current Needs and Future Demands*

The interactive activities were developed combining several technologies, such as PHP, MYSQL and HTML 5. PHP and MYSQL are two of the most popular Open Source scripting languages. HTML5 is essential to design and develop high quality animations that load quickly and look great.


Fig. 3 Discovering some famous museums in London

Since the material was first designed to be offered to the museum's visitors, the website design and development remained focused on computer compatibility, as seen in Figs. 3 and 4. Nevertheless, in the near future, the museum intends to use its website to offer a small selection of interactive activities to the general public. Therefore, regarding the longevity and flexibility to update the project for future demands, this internal project is developed in full compliance with World Wide Web Consortium recommendations. Moreover, the entire project is designed to guarantee a user-friendly and functional system with great performance on mobile devices, as seen in Fig. 5.

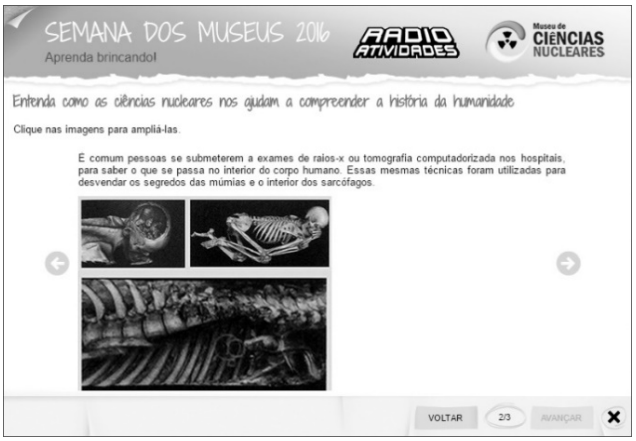


Fig. 4 X-rayed mummies at the British Museum


Fig. 5 Interactive activities for mobiles

## IV. Visitor Satisfaction Survey

The educational program for teachers and students at all levels defies existing negative public perceptions of nuclear science. Education and trust influence people's perceptions about the risks and benefits of this technology which helps us to maintain a high quality lifestyle.

A public satisfaction survey allows visitors to rate their experience at the museum on a 10-point scale, where 10 means a great experience. According to the last published results (Table I), among the 1,442 respondents, 88.6% of visitors gave a rating of 9 to 10, demonstrating that the Nuclear Science Museum does provide visitors with a high-quality learning experience, as seen in Fig. 6.

TABLE I
VISITORS' RESPONSE RATES FROM 2010 TO 2014

| Quantity | Rate |
|---|---|
| 1 | 0 |
| 1 | 6 |
| 1 | 6.5 |
| 14 | 7 |
| 12 | 7.5 |
| 102 | 8 |
| 35 | 8.5 |
| 256 | 9 |
| 66 | 9.5 |
| 2 | 9.6 |
| 6 | 9.8 |
| 14 | 9.9 |
| 933 | 10 |
| 1 | 0 |
| 1 | 6 |

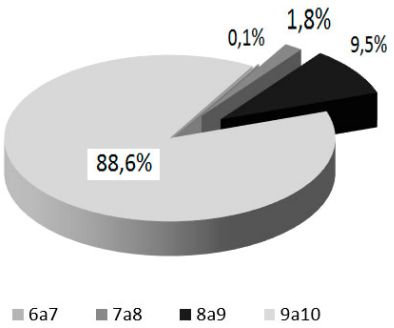


Fig. 6 Visitors' response rates from 2010 to 2014

## V. FINAL CONSIDERATIONS

The Nuclear Science Museum of the Federal University of Pernambuco, in Northeast Brazil, is the first and only Brazilian museum dedicated to nuclear science. The museum affirms its mission promoting new approaches to increase public understanding of nuclear science, providing accessible scientific information that reaches children and teenagers, as well as their parents and teachers, who are most often unaware of the matter.

Making use of modern educational concepts, such as interactive panels and multimedia learning tools, this initiative aims to dissipate unfounded prejudices providing the general public with well-founded scientific information. Interactive activities engage students and provide valuable learning. Feedback surveys have reported a high level of visitors' satisfaction, reinforcing the museum's main purposes of enjoyment and a high quality learning experience.

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