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Educating the Educators: Interdisciplinary Approaches to Enhance Science Teaching

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***Abstract*—**In a rapid-changing world, science teachers face considerable challenges. In addition to the basic curriculum, there must be included several transversal themes, which demand creative and innovative strategies to be arranged and integrated to traditional disciplines. In Brazil, nuclear science is still a controversial theme, and teachers themselves seem to be unaware of the issue, most often perpetuating prejudice, errors and misconceptions. This article presents the authors' experience in the development of an interdisciplinary pedagogical proposal to include nuclear science in the basic curriculum, in a transversal and integrating way. The methodology applied was based on the analysis of several normative documents that define the requirements of essential learning, competences and skills of basic education for all schools in Brazil. The didactic materials and resources were developed according to the best practices to improve learning processes privileging constructivist educational techniques, with emphasis on active learning process, collaborative learning and learning through research. The material consists of an illustrated book for students, a book for teachers and a manual with activities that can articulate nuclear science to different disciplines: Portuguese, mathematics, science, art, English, history and geography. The content counts on high scientific rigor and articulate nuclear technology with topics of interest to society in the most diverse spheres, such as food supply, public health, food safety and foreign trade. Moreover, this pedagogical proposal takes advantage of the potential value of digital technologies, implementing QR codes that excite and challenge students of all ages, improving interaction and engagement. The expected results include the education of the educators for nuclear science communication in a transversal and integrating way, demystifying nuclear technology in a contextualized and significant approach. It is expected that the interdisciplinary pedagogical proposal contributes to improving attitudes towards knowledge construction, privileging reconstructive questioning, fostering a culture of systematic curiosity and encouraging critical thinking skills.

***Keywords*—** Science education, interdisciplinary learning, nuclear science; scientific literacy.

I. Introduction

SCIENTIFIC and technological revolution presents considerable challenges to science teachers and the whole educational system. Beyond the traditional structure of the basic curriculum, contemporary education demands creative and innovative ways to enhance learning experiences integrating transversal themes from different fields of knowledge. Education in nuclear science is an example of an important contemporary challenge faced by Brazilian schools.

Nuclear science is crucial to improve lifestyle quality in modern society. Advanced nuclear medicine contributes to the fight against cancer. Nuclear research reactors produce therapeutic radionuclides for diagnosis and treatment of several diseases. Nuclear technology presents environmentally-friendly solutions on controlling the population of disease-transmitting mosquitoes, to prevent vector-borne diseases. Moreover, nuclear technology plays a crucial role in preserving cultural heritage, making use of unique techniques to date paintings and archeological findings and to unlock the secrets inside sarcophagi and mummies. Food irradiation is another beneficial application to reduce microbial contamination, preventing foodborne illness and food losses due to deterioration. Nuclear technology is also used in smoke detectors and security baggage x-ray scanner, saving lives every day. However, in Brazil, there is still lack of information and nuclear science remains a controversial theme [1].

Nuclear science is one of the transversal themes to be integrated in classroom. In fact, the new curricular standards - known as the National Common Curricular Base – establishes that schools are responsible for providing a fair information to enable students to develop skills and competencies for a deeper understanding of nuclear reactions and their applications [2]. Nevertheless, teachers themselves seem to be unaware of the issue, most often perpetuating prejudice, errors and misconceptions [3]. Since one of the recommendations of the national curriculum is the interdisciplinary teaching of the transversal subjects, teachers from different disciplines seek professional improvement to deal with their own knowledge gaps. To help schools and teachers throughout the country, our group started the development of an interdisciplinary pedagogical proposal to include nuclear science in the basic curriculum, in a transversal and integrating way.

II. Methodology

It is a great challenge to bridge the gap between nuclear science and society, integrating it in the traditional curriculum. Moreover, one of the current educational demands in Brazil is to promote meaningful learning. In elementary school, the most interesting way to learn science is to relate it to life itself. Therefore, among the several beneficial applications of the nuclear sciences, the authors chose a crucial theme in Brazil: food-supply-chain and food safety. From this theme, it is possible to introduce nuclear techniques and explain its concepts, processes and industrial applications. The protagonist of this project is one of the most popular fruits in Brazil and one of our great export products: the mango. All the content on food irradiation is introduced with the aid of comics, texts, research proposals and exercises.

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The material consists of an illustrated book for students, a book for teachers and a manual with activities do be developed in class. These educational materials count on high scientific rigor and articulate nuclear technology to current social perspectives, such as food safety, public health, food supply and foreign-trade policies.

The didactic material was created based on the analysis of the normative documents that define the requirements of essential learning, competences and skills in basic education for all schools in Brazil [2], [4]. The methodological proposal was elaborated according to the best practices to improve learning processes, privileging constructivist educational techniques, with emphasis on active learning process, collaborative learning and learning through research.

A. Interdisciplinary Teaching

Nuclear reactions and their applications are an integral part of the school curriculum; a new and controversial theme that has not been taught to teachers. The teachers´ manual brings further information and activities to articulate nuclear science to different disciplines: Portuguese, Mathematics, Science, Art, English, History and Geography. An example is the analysis, interpretation and construction of charts about food diseases in the country, considering time, distribution, geographic locations, causative agents, affected populations etc. According to the BNCC recommendations, analysis, interpretation and construction of charts are abilities to be developed in mathematics classes.

B. Learning through Research

The material encourages the reflection and development of critical thinking, under the controversial theme of the nuclear sciences. The activities include problematization of daily life, reading, written productions and the ability to articulate science and society. Teachers propose problem-based situations, always within the capacity of response of the student, inviting the students to new thoughts, to raise hypotheses, to develop argumentation and to build new knowledge. An example is the research about the diseases caused by salmonella. In what foods is it found? How can it cause cross-contamination in the consumer's home? What alternatives do we have to reduce the incidence of salmonella in meat, poultry or raw fish? What are the advantages and disadvantages of heating, freezing, using chemicals and food irradiation for the reduction of salmonella in such cases? The problematization of daily life leads to new perspectives and the ability to express scientific-based self-opinions.

C. Fostering Teamwork

The national curriculum recognizes teamwork as an important skill to be developed. In this sense, the didactic material promotes the student's commitment to collective production. Some activities aim to articulate different previous experiences of the students, privileging different skills to achieve a collective result. Beyond the ability to discuss and to respect different opinions, teamwork promotes the respect for heterogeneity, including different learning modalities and different cognitive styles. An example is the survey about food losses and waste: students are divided in small groups to interview different sectors of the school community (directors, cafeteria, other students). They should ask and write about: (1) food contamination and infestation (2) better techniques for food preservation, and (3) how to improve food safety. Each group presents the results to the class, discussing actions to promote food safety and avoid losses and waste.

D. Promoting Reconstructive Questioning

It is a fact that food is one of the great issues of our country. Although Brazil is a major producer and exporter of food, part of the population does not have access to quality food. Economic issues, food safety and the fight against waste are some of the aspects addressed in this book, in a creative and interdisciplinary way. Un example are the edible flowers. Beyond elegance, color, fragrance and flavor, edible flowers have several nutrients, including vitamins and minerals. Moreover, in Brazil, the commerce of these products has grown, due to the strong demand of the “gourmet food market”. Students learn that even if flowers are kept refrigerated, they generally last from 3 to 7 days. And there are important losses due to insects. It is obvious that it is forbidden to consume edible flowers with pesticides or other chemicals. Food irradiation can increase shelf-life of the flowers to about 15 to 20 days, without losing nutritional properties, color, texture, fragrance or flavor. Which other good options are there to increase shelf-life, decreasing prices and avoiding losses and waste?

E. Collaborative Learning

Teamwork provides a collaborative learning in which each student places his/her previous experience for the benefit of the whole team, connecting knowledge, stimulating further research and collaborating for the collective construction of knowledge. In addition, collaborative work fosters the development of cognitive, affective and relational skills. An example is the analysis and interpretation of normative / legal text. One of the ways of exercising citizenship is the ability to read and analyze laws, norms, decrees, resolutions and regiments, among others. Interpreting a law is different from interpreting a newspaper or magazine text. Students will have the opportunity to know legal terms and their hierarchies while analyzing Resolution RDC No. 21, of January 26, 2001, about food irradiation in Brazil [5]. Working in small groups is emphatically suggested, so that students can discover, discuss, interpret and comment on the text together.

F. Use of Digital Technologies

The digital technologies for instruction can expand the learning experience, improving interaction and engagement. In order to motivate and challenge students of all ages, this pedagogical proposal makes use of Quick Response Codes (QR codes), which enable instant access to videos, web sites and interactive activities. One example is the researches about food irradiation, which is a great technique in some cases but not in others. Students are taught that the choice of a preservation technique depends on achieving the best results where other techniques can not reach. Raw meat and flowers

petals are good examples. Nevertheless, food irradiation is not indicated for high-fat foods. To teach this topic, the student is directed to an interactive exercise through Internet, where there are many types of food (fruit, vegetable, meat, nuts, juice, ice-cream and even dog food). Students learn, case by case, when and why food irradiation is a good option or when and why food irradiation should be avoided. The exercise may be performed with the student´s own cellphone with great quality.

G.Education for Citizenship

It is expected that students can extend their knowledge beyond the walls of the school, identifying real possibilities of actions and social changes. One example is the waste levels of non-conventional parts of vegetables and fruits. Ignored by the Brazilian consumer, leaves, peels and seeds are thrown into the garbage containers. The beet leaves, usually ignored by the markets and the consumers, are usually thrown into the trash can. Nevertheless, they are antioxidant sources and contain: fibers, phosphorus, zinc, magnesium, potassium, copper, manganese, calcium, iron, vitamin A, vitamin B6, vitamin C and vitamin K. Each student is invited to face national issues and possibilities, acting as an agent of change, informing his/her family and his/her community, breaking with the culture of waste. In this sense, the book discusses the use of agrochemicals and other food preservation techniques, as well as recipes and nutritional information about parts of food usually neglected (by lack of knowledge). This is how school can teach citizenship.

III. Discussion

In order to create effective educational science programs, experts must communicate cultural, economic, and political benefits, articulating theory and life. As a matter of fact, one of Brazil´s largest social issue is food availability for our citizens.

Brazil is a major food producer and food exporter. Still, a large part of the Brazilian population does not have access to proper food in quantity and quality [6]. Economic issues and food safety are two of the biggest priorities to combat hunger and malnutrition. Significant food losses occur in the whole food supply chain. It begins during the production, due to infestations or inadequate harvest techniques. There are also losses and waste during post-harvest, processing, packing, transport, storage and commerce, due to the deterioration of food products [7]. National and international food programs encourage producers, commerce and consumers, providing information and solutions to ensure food safety and quality. Moreover, the national government invest in food programs to schools and communities. Indeed, consumers themselves are key actors in food waste: every day, every Brazilian family throws away 353 grams of food, which will no longer be consumed and will end up in garbage containers. This means that each Brazilian family wastes an average of 128.8 kg of food per year [8]. Changing the “food waste culture” is a must and a challenge in this huge country that tries to fight against hunger and malnutrition.

Nuclear techniques present alternatives to respond to this demand. Food irradiation is a safe and effective preservation technique to eliminate insects and parasites and reduce disease-causing microorganisms. The process helps to inhibit sprouting and delay ripening, prolonging the shelf-life of fresh fruits and vegetables. Food irradiation contributes to human health, food safety, environment issues and international commerce. Nevertheless, there is still great misunderstanding about the peaceful applications of nuclear science among a great fraction of Brazilian population [3]. Most often the media and social networks tend to associate radiation to major accidents, soil contamination and the exposure of plants and animals to radioactive pollutants.

On the other hand, Brazil, one of the largest food producers in Latin America, makes great use of over 1,000 pesticide products, and the government has already approved dozens of new pesticides to increase competition and decrease the cost of food products [9].

The great use of agrochemicals is a reality in Brazil and pesticides may be necessary in many cases. Nevertheless, teachers and students can only discuss the issue if they have a global knowledge to compare and analyze all options. This pedagogical proposal intends to present a fair understanding of the beneficial applications and real contributions of nuclear science and technology. The intention is to expand the repertoire of the student, offering reliable information, promoting reconstructive questioning and developing critical thinking, so that the student - with ample information - can express his opinion. Society´s judgments and decision making are directly linked to perceived benefits and risks. Teachers and students ought to have access to global information to be able to discuss the benefits and harmful effects to human health and environment among the several scientific advances.

IV. Expected Results

The purpose of pedagogical material is to assist teachers and students in the collective construction of knowledge, encouraging research, and technological development in Brazil, offering new perspectives in students' personal lives and professional choices.

Regarding the personal sphere, it is expected that this science program will contribute foster citizenship, so that the student will be able to develop critical thinking, to analyze situations from different perspectives, to discuss information from the media and to build scientific-based self-opinions. The students are supposed to participate as active citizens in their communities and in decision-making processes concerning the whole society.

Regarding the professional context and future choices, it is our intention to encourage the interest in science and technological development, fostering systematic curiosity, contributing to the development of new skills and abilities.

V. Final Considerations

This article responds to a contemporary challenge: the development of innovative pedagogical proposals to teach

science education in a transversal and interdisciplinary way. According to the new recommendations for Brazilian schools, emitted by the National Basic Common Curriculum (BNCC):

> "It is up to the education systems and networks, as well as the schools, in their respective spheres of autonomy and competence, to incorporate curricula and pedagogical proposals into contemporary themes that affect human life on a local, regional and global scale, preferably in a transversal and integrating way". [2]

Among the transversal themes that affect human life at a local, regional and global scale, the BNCC highlights food and nutrition education [10].

This pedagogical proposal intends to teach nutritional education together with another transversal theme: nuclear science, which is also a required curricular component, to be incorporated and arranged with the regular disciplines. The didactic material was entirely developed in compliance with the BNCC´s requirements. It is emphatically recommended that natural sciences and technology should be presented in an integrative and interdisciplinary way:

> "It is proposed that students analyze the complexity of processes related to the origin and evolution of Life (in particular of human beings), the planet, the stars and the Cosmos, as well as the dynamics of their interactions, and the diversity of living beings and their relation to the environment. This implies, for example, considering broader models when exploring some applications of nuclear reactions in order to explain stellar processes, geological dating and the formation of matter and life, or to relate biogeochemical cycles to the metabolism of living beings, to the effect and climate change.
>
> The social, historical and cultural contextualization of science and technology is fundamental for their understanding as human and social undertakings. At BNCC, therefore, it is also proposed to discuss the role of scientific and technological knowledge in social organization, in environmental issues, in human health and in cultural formation, that is, to analyze the relations between science, technology, society and the environment. The contextualization of the knowledge of the area surpasses the simple exemplification of concepts with facts or everyday situations. Therefore, learning must value the application of knowledge in individual life, in life projects, in the world of work, favoring students' role in addressing issues of consumption, energy, safety, environment, health, among others. [2]

The theme of the nuclear sciences remains a mystery for a great fraction of the Brazilian society, including parents and teachers, who have not been taught at school and most often do not know how to discuss the subject. Nuclear technology is part of our daily lives and it is necessary to bring young people closer to this reality in a natural and investigative way, demystifying the theme, deconstructing prejudices and unfounded fears. This innovative material was developed to respond to the contemporary challenges for science teaching, approaching science and life, promoting meaningful learning, encouraging young Brazilian students to research and technology.

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