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SOCIAL REPRESENTATIONS OF ETEC TEACHERS ABOUT NUCLEAR TECHNOLOGY

REPRESENTAÇÕES SOCIAIS DE PROFESSORES DE ETEC SOBRE TECNOLOGIA NUCLEAR

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RESUMO

Este artigo apresenta um estudo que visa compreender a representação social da tecnologia nuclear feita por um grupo de professores e coordenadores de Escolas Técnicas Públicas (ETEC) do estado de São Paulo. Após este grupo ter participado em palestras ministradas por pesquisadores do Instituto de Pesquisas Energéticas e Nucleares (IPEN), que incluíram visitas ao Instituto e ao Reator Nuclear de Pesquisa IEA-R1. O estudo foi realizado por meio de questionários semiestruturados. Os resultados demonstraram que, para a maioria dos participantes, a representação social da tecnologia nuclear mudou positivamente após um evento de três dias, mesmo que eles já tivessem algum conhecimento sobre o assunto. Também foi possível detectar alguns erros conceituais e corrigi-los, evidenciando que o contato técnico mais próximo foi fundamental para essa mudança.

PALAVRAS-CHAVE: ETEC; representação social; tecnologia nuclear; educação; divulgação científica.

ABSTRACT

This paper presents a study that aims to comprehend the social representation of nuclear technology made by a group of teachers and coordinators of Public Technical Schools (ETEC in Portuguese) from the state of Sao Paulo. After this group had taken part in lectures given by researchers of Nuclear and Energy Research Institute (IPEN in Portuguese), which included visitation to the Institute and to the Nuclear Research Reactor IEA-R1, the investigation was performed using semi-structured questionnaires. The results demonstrated that for most participants, the social representation of nuclear technology positively changed after the course of a three-day event, even if they already had some knowledge about the subject. It was also possible to detect some conceptual mistakes and correct them, making evident that closer technical contact was crucial for this change.

KEYWORDS: *ETEC; social representation; nuclear technology; education; scientific divulgation.*

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INTRODUCTION

How are technologies presented to society? Is nuclear technology presented differently? How is scientific knowledge received by the public? Is the public opinion relevant enough to influence or interfere in political decisions?

Public opinion is important for the acceptance of different technologies and is a longstanding concern of specialists in different areas, considering that specialists and the public, in general, may have distinct and sometimes conflicting views and experiences. This also happens in the case of Nuclear Technology.

In the end of the 19th century up to the 1st World War, a period often known as the *Belle Époque*, the European society had a great number of scientific discoveries and science started playing an important role in daily life through inventions that altered it significantly (L'Annunziata, 2016). At the same time, Nuclear Technology (NT) gained popularity, relevance and societal interest, which gave reasons for the application of such technology, such as radioactive drinks, toys, cosmetics and therapeutic treatments (Lima; Pimentel; Afonso, 2011). At that time, the risks of radioactivity were not yet known.

The public acceptance of NT has changed since World War II and the nuclear accidents that happened – Chernobyl in 1986, Goiania in 1987 and Fukushima in 2011, made evident the consequences of such accidents, like burns and cancer (Merçon; Quadrat, 2004; Martinez-López; Hande, 2020, p. 81).

Therefore, when there is a negative event in the nuclear area, some experts seek to assess the impacts that it can cause worldwide, like changes in policies due to public opinion (Latré; Perko; Thijssen, 2017). Another concern for experts in the nuclear area is the disposal and storage of radioactive waste and its impact on public acceptance (Ferreira; Soares, 2012).

Questions about how society behaves when facing social-environmental problems, in this case NT, is part of the scientific culture of individuals and how they can become subjects of the appropriate history (Caldas, 2010).

Studies carried out in Europe, in the last decades, focusing on public acceptance of NT demonstrated that there is little support for it. On the other hand, in some studies, the participants that possess a high socioeconomic level demonstrate wider concern about climate change, which is a factor that would tend to increase support for nuclear technology because it's free of carbon emissions (Sjöberg, 2004; Pampel, 2011; Kim; Kim; Kim, 2013, Perko, 2014).

Although NT is used in several areas such as health, environment, agriculture and others, the public in general has not been fully informed about the large range of its applications, but their knowledge is usually based on reports broadcasted by the media. According to BARATA, CALDAS and GASCOIGNE (2018) it is necessary to consider the contrast between expert and lay discourses intermediated by the media, because many changes in society are influenced by Science and Technology (S&T) and it is necessary that people have a wide understanding about science in order to give a basis for decision making in subjects relevant to society.

Another factor that contributes to the development of different opinions among society, on the nuclear theme, is the influence of personal experiences, mainly in emotional factors, such as Social Representations (SR) referring to the nuclear area (Kiipper, 2011). This author also states that these experiences (Chernobyl, Goiânia and Fukushima accidents) can motivate the empowerment of public decisions on the nuclear theme and therefore, future perspectives related to the nuclear area are dependent on public opinion, whether positive or negative.

Social Representations are part of the Theory of Social Representations (TSR) proposed by Moscovici, in 1969, to explain the interrelationship between the Subject and the Object (Moscovici, 1978). The TSR is based on the processes of building experience from its context

of origin, and considering the individual and collective knowledge in the formulation of SR. In this sense, the TRS is widely used to understand how human knowledge is constructed from its context of origin, thus contributing to studies that aim to understand the culture and social practices of different groups (Santana *et al.* 2014).

Therefore, reflecting on SR is referring to the knowledge produced by common sense (de Souza Santos, 2005, Bidjari, 2011). According to Jodelet (1994), SR is "a form of knowledge, socially elaborated and shared, with a practical objective, which contributes to the construction of a common reality to a social group". On the other hand, this fact raises the question of the dichotomy between representation and the object being represented, between the real and the imaginary. Still for this author, SR have fundamental characteristics as they always represent an object or individual, also having an imaginary, symbolic, constructive, autonomous and significant character, due to the possible mental replacement of a given object (person, thing, idea) to a new meaning (Marková, 2017).

Abric is another important author for SR, since in 1976 he proposed the Central Nucleus Theory, a structural approach, known for prototypical analysis, widely used today in the SR study (Wachelke; Wolter, 2011). In this approach, SR would be governed by two components, the central nucleus (CN) and the peripheral system (Abric, 1998, p. 27). The first refers to the CN of the representations, which is related to *historical, sociological* and *ideological* conditions and, thus, marked by the *collective memory of the group*. The second component is more sensitive to changes and is determined by immediate conditions and contexts. Hence, it is necessary to consider these two aspects, because, according to Machado and Aniceto (2010) it is not enough to infer such representations from the discourse, it is necessary to relate the data to that which comes from the investigation.

Within this perspective, the objective of this article was to present the results obtained, regarding the investigation of the SR of São Paulo ETC´s (State Technical School) teachers, who participated in a course conducted by the Energy and Nuclear Research Institute (IPEN) researchers.

The three-day course's first objective was to bring IPEN closer to education professionals, and in addition, to promote scientific knowledge dissemination, aiming to reflect on how to improve participants' knowledge and understanding on the nuclear theme. Within the proposed activities, a visitation at the IPEN research center was planned to the *Radiopharmacy Center*, the site of the production of radiopharmaceuticals used in diagnosis and therapies, and to the *Radiation Technology Center*. The highlight of the visitation was to the laboratory of Ionizing *Radiation in Food and Agricultural Products* (Cobalt multipurpose irradiator - 60), and to the *Research Reactor Center* to learn about the IEA-R1 nuclear research reactor, dedicated to research in the fields of nuclear physics, health, agriculture, environment and archeometry among other applications.

The initial assumption of the work was that if more and more Basic Education teachers are better acquainted with nuclear technology, they will be able to disseminate the knowledge learned to their students with a more critical and realistic view, not only presenting the negative aspects propagated by the media, but also highlighting the benefits in health and industry applications, a fact that would favour a more positive and safer image of nuclear technology.

METHODOLOGY

The present study had a qualitative and quantitative character in the form of a case study, understood as a "deep empirical investigation about the contemporaneous phenomenon and its context in the real world, especially when the limits between the phenomenon and the

context are not clearly evident" (Yin, 2015). In addition, it is an eclectic technique for data collection and a delimited, unique and singular system (Ventura, 2007; Coimbra; Martins, 2013)

In this case study, a group of teachers from the São Paulo State Technical Schools (ETEC's in Portuguese) was analysed and the TSR was used as the main theoretical reference, complementing the Abric Central Nucleus Theory to analyse the evocations formulated by the participants. The technique used was the Free Evocation of Words (FEW), proposed by Abric (1998), and such evocations were associated with the elaboration of a text.

With the evocations obtained, a qualitative analysis was carried out considering the similar meanings between the terms, and then, a grouping into different categories was carried out. After the qualitative procedure, data analysis was performed.

Data collection instrument

A structured questionnaire of an exploratory nature was applied to the participants with the purpose of raising the prior knowledge of these educators regarding nuclear technology, in addition, the possible SR that they share among themselves. This questionnaire contained questions regarding the characterization of the participants (age, education, sex, knowledge area) and some questions sought to know the participants' understanding on nuclear technology applications or concepts and the SR of participants related to NT. At this moment, the participants were invited to write a sentence containing words that the term "nuclear technology" is related to for them. The questionnaire was applied in two moments of the course, both before and after finishing, in order to assess whether or not there were movements in the participants' SR structure.

Social Representations

Considering the qualitative and quantitative properties in determining the central and peripheral elements of SR, FEW were used. This is a technique designed to collect the constituent elements of the content of a representation from its lexical universe, due to its spontaneous character, allowing for faster and easier access which makes the method more advantageous. The term "Nuclear Technology" was adopted in order to obtain a more spontaneous and random result (Abric, 1998).

The software used, entitled Invocado, was developed by a researcher at the Pontifical Catholic University of São Paulo (PUC-SP), as an adaptation of Evoc2000, created by Pierre Vergé (Perez, 2008), with a simpler interface.

Each evoked word has a certain frequency, however to analyse the SR it is interesting to know the meaning used for all evocation through qualitative treatment, that is, if all evocations are present in this category have the same meaning. It is noteworthy that there are terms present in more than one category because of the meaning and phrase formulated by one participant may have represented it differently from another participant. For this reason, it is necessary to investigate the sentences with the most frequently evoked five words, so the analysis presented is more consistent, representative and cohesive.

The combination of Frequency and Average Order of Evocations (AOE) shows us the positioning in the quadrants in which a category is located, which is CN, that comprises words with high frequency and low evocation order, the First Periphery (FP) brings together the latent and the most frequent peripheral elements, that is, high frequency and high AOE, the Contrast Zone (CZ) presents responses with low frequencies that are promptly evoked, indicating two possibilities: I. the terms are complementary to the FP; II. there is a subgroup of elements distinct from the majority, perhaps even with a different central nucleus - and Second Periphery (SP), which presents terms that are evoked as last answers (Wachelke; Wolter, 2011).

These factors allow investigating the centrality of the representations of the elements through the construction of the diagram with four quadrants, allowing us to discuss the centrality regarding the social representations of the interviewees.

RESULTS AND DISCUSSION

Characterization of Participants

Thirty seven questionnaires were answered, with the average age of the participants being 45 years old, 60% female and 40% male. The predominant area of knowledge among the educators was Exact and Earth Sciences with 46%, followed by Engineering with 15%, Biological with 8%; Humanities, Health and others with 5%, Social Science Applied with 3% and 10% of the participants did not answer. In addition, 84% of the public studied had a postgraduate degree.

Social Representations

When requesting free evocation of words, with the inducing stimulus "Nuclear Technology", the participants elaborated a total of 185 evocations from the inducer term, at both times of the questionnaire application. However, before generating the diagram to verify the possible social representations of the participants, a qualitative treatment of the terms mentioned was carried out. The purpose of this term reduction was to facilitate the understanding of the results obtained with the free association of words (Missias, 2015).

To make such an association, evocations qualitatively were evaluated together with the corresponding phrases formulated by the participants, seeking the similarity of terms, synonyms and meanings, both grammatically and semantically. Of the 185 evocations before and after the course, they were grouped into 11 distinct categories (quantitative analyses), which consider the terms evoked with similar meanings, for example, the terms atoms, electrons, neutrons, nucleus are present in the *Atomic Structure* category; as well as garbage, waste¸ environment and care are in the Environment category.

When generating the diagram (Table 1), the average frequency of evocations was 15 and the AOE was 2.65. The two factors determine the positioning of the category in the four quadrants of the diagram, thus, the category with a frequency higher than 15.2 was positioned in the upper quadrant, CN and FP, because they are also the most frequent. In the same way, the average position of citations below the value of 2.65 defines the positioning of the category in the left quadrants, CN and CZ. Finally SP (below, right), gathers the elements that are a little less present or less important in the field of representations.

Table 1: Diagram structure of social representations, before the course.

	Inductive term: nuclear technology Minimal frequency of evocations = 2					
	Mean evocation order < 2.65			Mean evocation order ≥ 2.65		
	Central Nucleus (CN)			First Periphery (FP)		
		FREQUENCY	**AOE**		**FREQUENCY**	**AOE**
Frequency	Technology	27	2.11	Accident	16	2.94
	Energy	50	2.30			
	Contrast Zone			Second Periphery		
Frequency	Safety	2	2.50	Radioisotope	3	3.00
	Aplications	12	2.42	Medicine	9	2.89
	Enviornment	13	2.62	Atomic structure	9	3.00

<15.2	Risk	11	2.73

AOE: Average order of evocations

At first, the participants evoked terms related to technology and energy, probably because the inductive term itself has these words, and energy production is a possible application of the nuclear area, according to some phrases elaborated by the participants, they showed: "The production of nuclear energy occurs through the heat yield…"; "The energy generated in nuclear plants is efficient."; "Nuclear plants contribute to technological development".

In the first periphery there is only one category, considering it to be very representative because it may reinforce the categories present in CN (Moliner; Abric 2015, p. 83) and there are terms that recall the nuclear accidents, i. e., Chernobyl, Goiânia and Fukishima. In one of the phrases formulated, the participant says "I learned about radiation when the accident in Goiânia with cesium 137 occurred, due to the inappropriate disposal of an x-ray or radiotherapy device. I also learned that uranium is a material that causes radiation". We highlight that, for this participant, the Goiânia accident was relevant to him to the point of mentioning it when he was asked about NT, even though it presents some conceptual errors.

Despite this initially negative aspect within the diagram it was found that the participants also related the inducer term with possible benefits and development, for example, the applications of nuclear technology were remembered by a subgroup of participants, just as there was a group concerned with the possible environmental impacts that can be caused by nuclear technology, as in the phrases "nuclear plants contribute to technological development, however radioactivity must be used safely so as not to endanger people and the environment"; "An atomic explosion emits rays that are differentiated causing contamination in the environment and food, causing the process of cellular alteration in the human organism, which through nuclear technology itself can try to correct the problem, diagnose and treat it".

Health-related terms were mentioned in the SP, which can demonstrate knowledge related to nuclear medicine, according to the participant's phrase "The production of nuclear energy occurs through heat yield and this technology can be used in medicine for treatment, or in agriculture, improving seeds ... " and, interestingly, the risk category had an average frequency justifying its positioning in this quadrant, one of the participants formulated the phrase:" the nuclear power plants, they contribute to technological development, but radioactivity must be used safely so as not to put people and the environment at risk ". This last sentence demonstrates a certain acceptance of nuclear technology, as well as socio-environmental concerns.

At the end of the course, the questionnaire was reapplied to check if there was a change in the group's social representations. The new 185 evocations were analysed and grouped in the same 11 categories of the pre-course evocations (Table 2) and a new evocation diagram was generated.

Table 2: Diagram structure of social representations, after the course.

	Inductive term: nuclear technology Minimal frequency of evocations = 2					
	Mean evocation order < 2.58			Mean evocation order ≥ 2.58		
	Central Nucleus (CN)			First Periphery (FP)		
		FREQUENCY	**AOE**		**FREQUENCY**	**AOE**
Frequency	Application	20	2.35	Medicine	24	2.75
	Energy	28	2.14			
≥14.3	Technology	33	2.58			
	Contrast Zone			Second Periphery		
	Accident	2	2.00	Other	2	3.50
	Safety	9	2.11	Environment	7	3.14

Frequency	Atomic structure	8	2.63
	Radioisotope	10	2.60

AOE: Average order of evocations

At this moment, the risk category is not present because the term was mentioned only once, which can be considered as representative of the improvement in the social representation of the participants related to the term risk in the nuclear area. Table 2 shows differences from Table 1 in relation to the position and frequency of the categories.

The category Miscellaneous was not present in Table 1 due to its low representativeness, since only one evocation was made in that category.

Under NC the category Applications was added, leaving the contrast zone due to the increase in its frequency. The PP was positively altered, as the category Medicine confirms in the NC, while Accidents, which had less frequency and *Safety* are found together in the ZC. In SP there was a rearrangement of the category with variations in the frequency and OME generated by the program, also the insertion of the Environment category due to the decrease in its frequency.

The phrases formulated in the pre-course showed concern about the possible risks that NT may present, in the perspective of the studied group. We also noticed some conceptual errors in the formulations, for example: "the radiation occurs through the reactor where the energy comes from the nucleus of the radioactive element"; "Radioactivity is potentially dangerous due to the nuclear fission that happens to atoms. Another problem with radioactivity is nuclear waste and we cannot forget the case of the Chernobyl accident".

After the course, the requested phrases did not present many conceptual errors and the participants expressed the benefits of nuclear technology and a little learning of the course, according to the phrases: "On a visit at IPEN I met the nuclear reactor, the radiopharmaceuticals and learned that radiation can be beneficial. "; "Nuclear energy, previously seen as dangerous radiation, is being treated as a technological evolution in the scientific world, as it is being used as a medical treatment to defeat cancer".

This event highlights the importance of education in the scientific dissemination processes, as the SR changes were possible due to the experience proposed by a scientific institution and the availability / interest of the participants. In addition, educational processes are essential for the appropriation of scientific knowledge and broad reflection on the topic in question (Romero-Rodríguez *et al*. 2020). Considering theoretical knowledge issues, the group was asked about the difference between radiation and radioactivity[1], and was asked to write a sentence explaining each of the terms. Such phrases were analysed and categorized as *correct*, *incorrect, with errors* and *do not know*. Initially, 51.4% and 27% of the participants were able to answer correctly what is radiation and radioactivity, respectively. After that this percentage increased significantly.

However, although the comprehension about radiation and radioactivity have improved, it was perceived as a greater difficulty in responding correctly about the concept of Radioactivity, as can be seen in Figure 1.

Another question asked to the participants, before and after the course, demanded comments about the statement *"An irradiated material, for the purpose of biological decontamination, becomes radioactive."* The answers obtained were analysed by categorizing them as *correct, incorrect, contains errors* and *did not answer*, as shown in Figure 2.

[1] It can be understood that *Radiation* is the energy propagation in the form of electromagnetic waves or particles, while *Radioactivity* is the phenomenon (Cardoso, 2001)

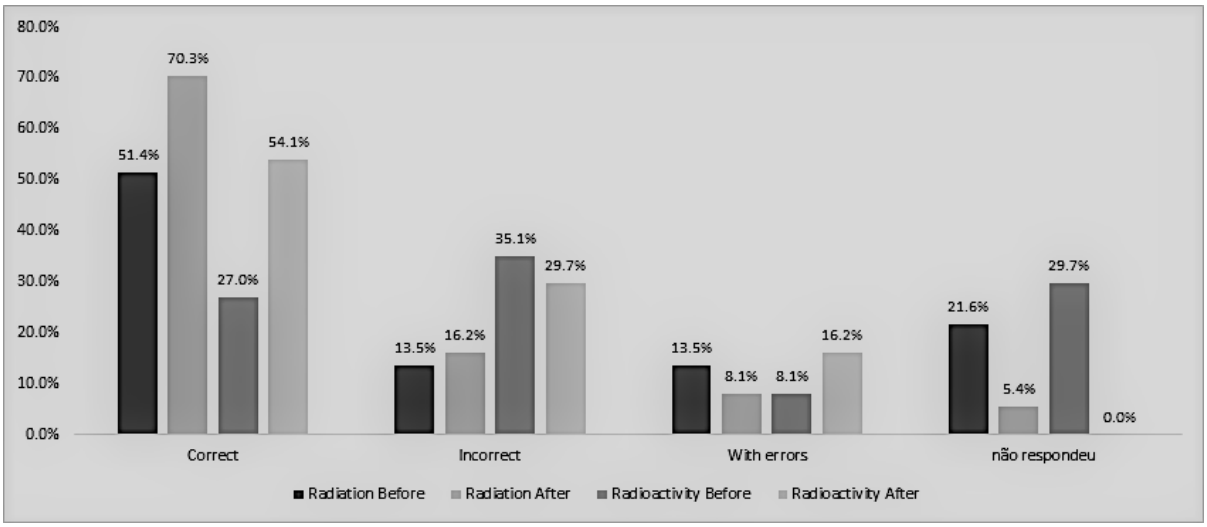

Figure 1: Analysis of radiation and radioactivity concepts before and after the course. Font: authors

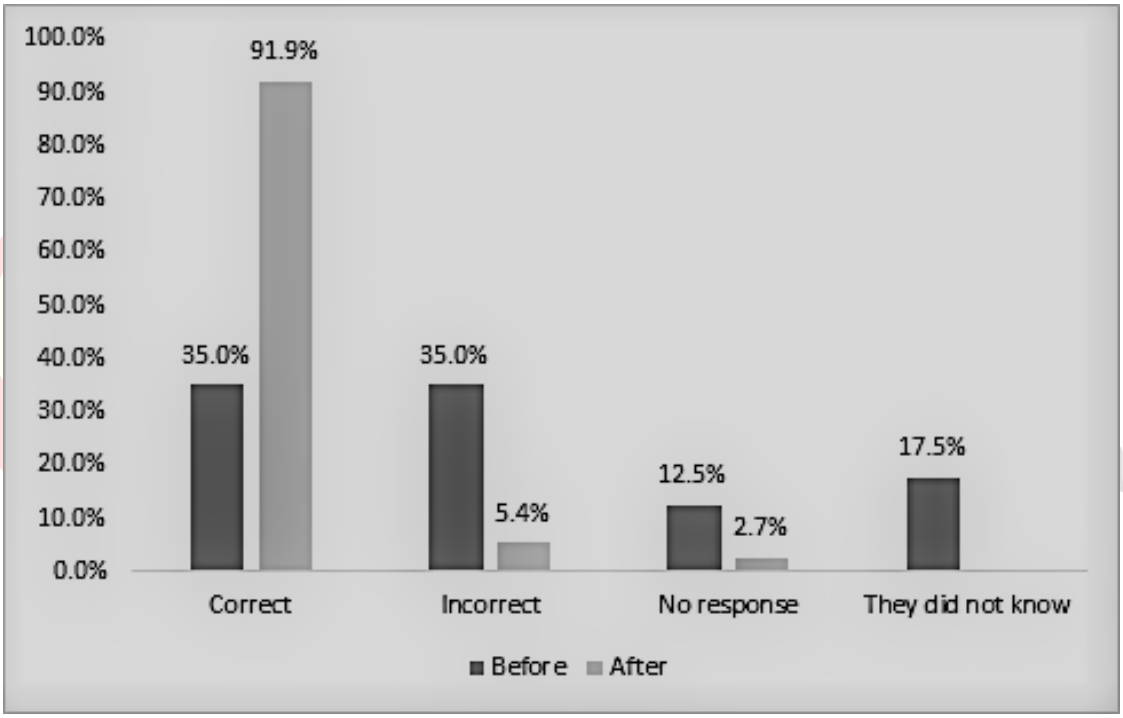

Figure 2: Analysis of responses regarding biological contamination before and after the course. Font: authors.

According to the analysis, there was a great distinction in the two moments of the questionnaire application. The completion of the course, as well as the participation of the group, was fundamental to improve the understanding on the subject. According to Cardoso (2001) "contamination, radioactive or not, is characterized by the undesirable presence of a material in a certain place, where it should not be. Irradiation is the exposure of an object or a body to radiation, without direct contact with the radiation source. [...] To irradiate, therefore, does not mean to contaminate". The subject of biological decontamination was better understood by participants and possibly has influenced the category *applications* in CN of the second diagram (Table 2)

Another stigma faced by the nuclear area is that radiation or radioactivity can be a possible cause of cancer. According to a study made by Barbosa and França-Botelho (2011), the group

studied by them was only a little informed about relevant issues of cancer prevention and control, their treatments, and predictions.

In this case study, the question was correctly answered by the participants and was necessary for a better understanding and cleared up some doubts on the subject (Figure 3).

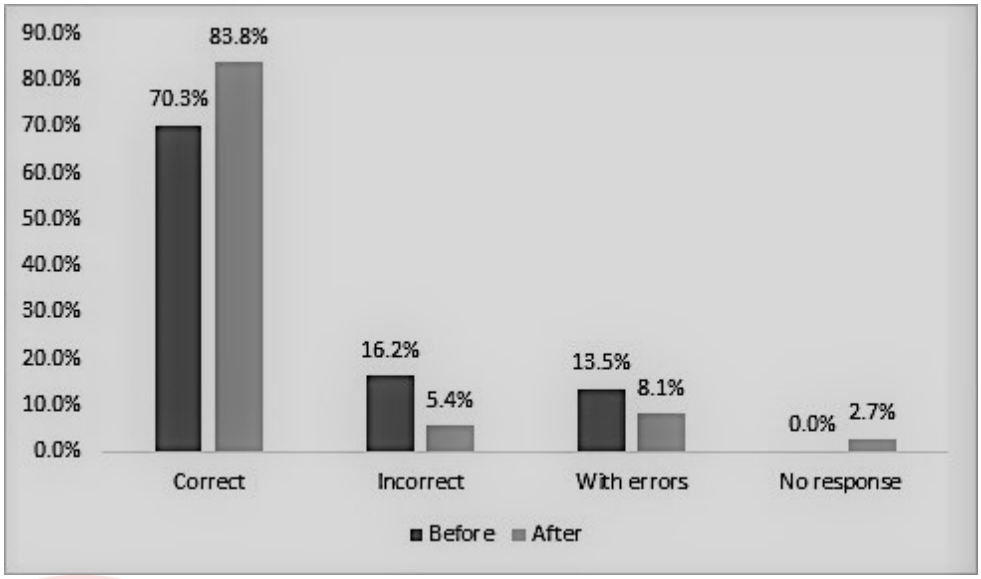

Figure 3: Analysis of the participants' responses and their understanding of the possible relationship of radioactivity being the cause of cancer before and after the course Font: authors.

Participants were also asked more specific questions. For example, they were asked to mention examples of radiopharmaceuticals, in both moments. The answers were analysed and, as expected, there was a great abstention or they did not know how to answer before the course. After that, the results were mostly correct and with little abstention (Figure 4).

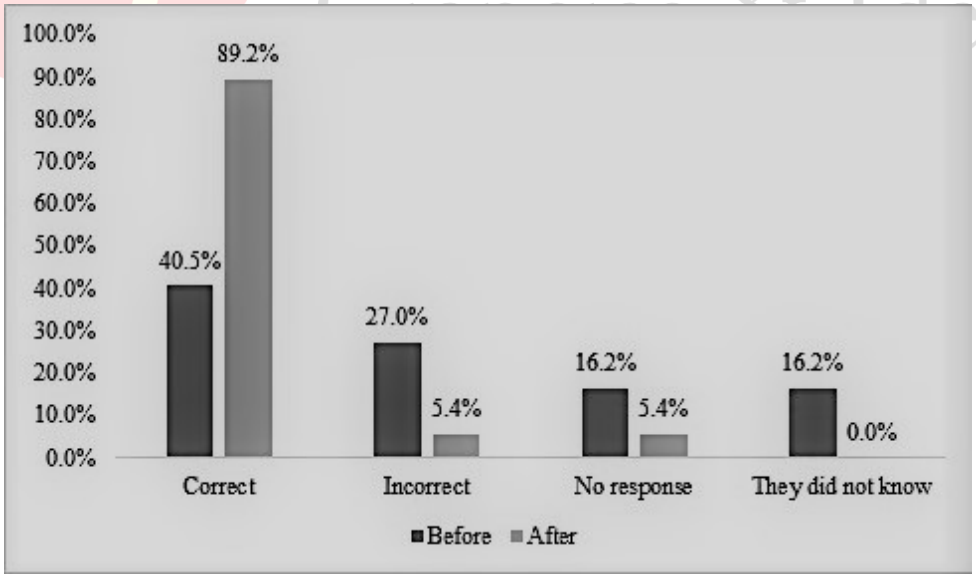

Figure 4: Analysis of responses regarding radiopharmaceuticals before and after the course

Font: authors.

Another specific question refers to the forms of radioactive decay. Participants were asked about how many forms of radioactive decay they knew. With the answers obtained, an analysis was carried out to verify the number of correct answers in the two moments of the research (Table 3).

Table 3: Comparison of answers on forms of decays and the number of correct answers in percentages.

DECAY	BEFORE	AFTER
1 form	5.4%	0.0%
2 forms	5.4%	0.0%
3 forms	21.6%	40.5%
Incorrect	24.3%	51.4%
They did not know	24.3%	0.0%
No response	18.9%	8.1%

Font: authors

For an improvement in the understanding of this group, perhaps it would be necessary to return to the subject or have had more time to discuss the topic, since the short time of the course was also a complaint from the participants, they would have liked to have had more time to delve deeper into the proposed content.

It can be noticed that the SR of participants in CN were kept for it is related to historical, social and ideological experiences. However, a new SR was added by the group: *applications*, i.e., when a participant thinks again about NT he will possibly relate it to terms in this category. The SP has been modified, because it is more sensitive for changes in SR, as well as the CZ. One can notice that the contact with IPEN has broadened the knowledge of the participants.

Despite the good involvement of the participants with the proposal, the social representations of teachers about nuclear technology, this research identified that the majority of social representations seem to be based on ideas related to accidents, dangers that already occurred, and stereotypes disseminated socially in relation to the nuclear area, according to Caldas (2010) due to the inevitable tensions between scientists and journalists that stems from their different knowledge and culture. As a consequence, part of this group considers applications in the nuclear area with reservations. However, the positive changes occurred after the course in the peripheral system, according to Sá (2002) concepts, may indicates that such evocations can be part of the NC in the future, which may favour the acceptance of the technology.

Thus, if the studied group knew more about nuclear technology and disseminate the knowledge learned to their students with a more critical and realistic look, highlighting the benefits, beneficial applications and their historical perspective, instead of prioritizing the negative aspects, the scientific dissemination regarding the nuclear area in a positive and safe way can be favoured.

The resultant NC obtained in the study revealed consensual terms of the studied group, which initially appears to be positive terms for the nuclear area; however, a more detailed analysis shows that there is resistance to the theme. This fact leads to a reflection on the need to carry out more studies of this type to verify the SR of different social actors on the nuclear theme.

CONCLUSION

The present case study allowed to conclude that the basic concepts introduced to the São Paulo State Technical Schools teachers, in the short-term course on nuclear technology, indicated

effectiveness for the studied group, even if some of them already had some fundamental knowledge about the subject. The changes in the SR demonstrated in the answer improvement of the participants, resulted from the closer contact with NT, during the visit to IPEN, in which it was possible to talk with professionals in the nuclear area, learn a little more about the manufacture of radiopharmaceuticals and applications of technology in everyday life and was fundamental to consolidate the bases of the scientific knowledge for the participants of the study.

It can be concluded that the concepts learned during the course may have helped for positively improve social representations, which can, in turn, contribute to the public opinion as the participants reckon NT when lecturing or talking about the subject for their students.

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