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SOCIAL REPRESENTATIONS AND CHOICE ENERGY: A MATTER OF EDUCATION?

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ABSTRACT

The development and use of Nuclear Energy in the history of mankind's many different energy matrixes is one of the most interesting. From the scientific standpoint, it was most definitely a success, however, from the political and public opinion standpoint, not so much. From its discovery until now, the risk perception of this power source has varied greatly in the opinion of the public and even in the scientific community in a direct relationship with the structuring and restructuring of the Social Representations (SR) of the population over time. Is it possible for education to convey the social object "Nuclear Energy" in a less negative way? Or to prevent emotional reactions of more aversion and developing unfavorable attitudes towards this technology? What is the influence of education on these SRs? With this in mind, this study aims at analyzing the restructuring of the SRs in this area by interviewing students of the Federal University of São Paulo (UNIFESP), future professors, in order to better understand the constructed SRs and, therefore, point to important information for the rethinking of practices for scientific and learning disclosure. The methodology used was free word association technique, which allows us to obtain the frequency in which each element was retrieved and the average order of retrievals, as well as a questionnaire with close-ended questions.

1. INTRODUCTION

Brazil will soon face a lot of changes in the civil area of national nuclear policy, remodeling the industry structure and setting efficiency goals. The government wants to increase the research in minerals of interest in the area, in the technology for uranium enrichment and fuel production, from the creation of a National Nuclear Energy Agency. Besides this institutional reform to accelerate investments in the area, the government also prepares a direct injection of $ 800 million in the development of multipurpose reactor, in São Paulo, to the research and production, for example, and application of radiopharmaceuticals in agriculture projects.

It is undeniable that if these measures are well implemented, for sure they will bring development to the sector both from an energy and social perspective. But what about the negative and restricted imaginary of the society for the Nuclear Technology? In this sense, researches which aim to know the public perception regarding this issue have been developed for decades, albeit timidly in Brazil, with numerous studies showing the degree of public support or opposition to nuclear power and how this support has varied over time. [1, 2].

However, a common belief among the technical community is that people are irrational, negatively biased and misinformed. And that education is the solution to all problems [3].

The more people understand about nuclear technology, the more they tend to favor it? Within this perspective, if the industry starts massive national advertising campaigns for public education will the problem be solved? The campaigns in this direction have been successful? What is the importance of education and teachers in this problem? What is the role of the SR in the course of this question, given that they go beyond the simple evaluation of the perception of an individual? And how these issues can impact the energy option of a country? With these questions in mind, this study aims to analyze the restructuring of the SRs in this area by interviewing students of the Federal University of São Paulo (UNIFESP), future professors, based on the inducers terms "Nuclear Energy" and "Chemistry Nuclear" highlighting the structure of the SR on the subjects and, therefore, point to important information for the rethinking of practices for scientific and learning disclosure.

2. METHODOLOGY

According to Spink (1999) [4], the investigation of SR can be made from spontaneous processes, regardless of if they are "by induced issues, expressed freely in interviews, or already crystallized in social productions such as books, documents, materials or memories of newspapers and magazines". The plural methodological character of research in the field of SR is presented by Farr (2002) [5], who states that the theory is compatible with the use of a wide variety of different research methods. In this study, the methodology used was the free evocation of words technique, given the frequency that each word was evoked and their average order of evocation [6], and oriented and structured questions.

Data collection was realized at the beginning and end of the semester the discipline of Chemistry II of mathematics and science education course - BSc in order to evaluate possívies restructuring of SR.

Data analysis was performed as follows: dictionary definition of the words evoked, quantification of the words evoked from evocations of frequencies in hierarchical levels and average order of evocation through the EVOC statistical program created in 2000 by Pierre Verger [7] to investigate the centrality of representations of the elements through the framework of four quadrants and the discussion of the centrality of social representations.

The initial assumption is that the terms that meet both the criteria for evocation and appear more often in first place, are supposed to have greater importance in the cognitive schemata of the individuals and would, therefore, be candidates for the core of representation [8].

A total of 104 students were interviewed in first phase of the study and 71 in second phase. Out of the total amount of respondents, 49% were female and 51% were male, 36% educated in private schools in the country and with an average age of 24.

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3. RESULTS AND DISCUSSION

3.1. Free evocation of words technique

With respect to freely evoked words, the results showed that the respondents performed the requested task by producing 947 evocations from 60 different words or expressions in the first phase and 647 evocations from 44 different words or expressions in the second phase. The number of words mentioned by students is considered to be relatively low, which may mean that some elements were shared by the group at the expense of other elements that are more idiosyncratic.

For the construction of the quadrants, words that were mentioned only once or twice were removed since such represented a percentage of under 10%, which is considered insignificant. A little over 90% of the words evoked were used and this enabled the analysis to be considered more consistent, representative and "clean". We obtained the average frequency of 10. The average order was obtained by dividing the number of invocations per respondent by the number of respondents. Every interviewee evoked 5 words, the average order was 2.5 evocations per person. Based on these criterions, it was possible to construct the diagram with four quadrants (Table 1, Table 2, Table 3 and Table 4).

Table 1. Structure of social representations of students of the Federal University of São Paulo (UNIFESP), based on the inducer term "Nuclear Energy" – PHASE I

	Average Order of Evocation < 2.5			Average Order of Evocation >= 2.5		
	Central Core (CC)			First Periphery (FP)		
Frequency >=10	Bomb	13	1.571	Pollution	07	2.571
	Plant/Reactor	36	2.035	Danger/Risk	24	2.706
	Uranium	20	2.250	Waste	12	3.000
	Core	11	2.455	Radiation	32	3.129
				Fusion	08	3.250
				Radioactivity	12	3.300
				Technology	12	3.083
	Contrast Zone (CZ)			Second Periphery (SP)		
3<= Frequency <=10	Chernobyl	02	1.000	Simpsons	02	2.500
	Transformation	02	1.500	Chemistry	06	2.833
	Clean	05	2,000	Safety	04	3.500
	Progress	03	2.000	Health	02	4.500
	Protons	03	2.000			
	Renewable	02	2.000			
	Electrons	06	2.167			
	Reaction	04	2.250			

Table 2. Structure of social representations of students of the Federal University of São Paulo (UNIFESP), based on the inducer term "Chemistry Energy" – PHASE I

	Average Order of Evocation < 2.5			Average Order of Evocation >= 2.5		
	Central Core (CC)			First Periphery (FP)		
Frequency >=10	Chemistry	11	1.800	Environment	8	2.750
	Atom	37	1.806	Radioactivity	13	3.000
	Protons	9	2.222	Energy	33	3.061
	Core	24	2.292	Radiation	20	3.200
	Study	10	2.400	Reaction	14	3.364
	Fusion	12	2.417	Bomb	12	3.444
	Technology	9	2.444	Particles	8	3.625
	Electrons	13	2.462			
	Fission	16	2.467			
	Contrast Zone (CZ)			Second Periphery (SP)		
3<= Frequency <=10	Physic	4	2.250	Neutron	6	2.667
				Research	5	3.000
				Transformation	3	3.000
				Waste	7	3.500
				Uranium	6	3.500
				Development	6	3.500
				Reactor	4	3.750

Each quadrant has a specific function, according Abric [6]: (1) Central Core (CC), in which the words with more frequence and more readily evoked appear, remembering that it has the function of generating of the representation meaning, determine their organization and maintain its stability; (2) First Periphery (FP), which contains the salient peripheral elements, since they are also the most frequent; (3) Contrast Zone (CZ), in which are the themes evoked by few people, and, thus, low frequency, which, however, does not diminish its importance, because, according Abric may reveal evidence of the existence of a minority subgroup which it has a differentiated representation; (4) Second Periphery (SP), which, also according to the author, brings together the elements present less important in the field of representations.

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Table 3. Structure of social representations of students of the Federal University of São Paulo (UNIFESP), based on the inducer term "Nuclear Energy" – PHASE II

	Average Order of Evocation < 2.5			Average Order of Evocation >= 2.5		
	Central Core (CC)			First Periphery (FP)		
Frequency >=10	Atom	17	2.182	Radiation	15	2.533
	Energy	18	2.278	Uranium	19	2.632
	Accidents	10	2.291	Fusion	13	2.692
	Fission	15	2.467	Nuclear	15	2.800
				Danger/Risk	14	2.875
				Core	10	2.900
				Plant/Reactor	26	2.932
				Bomb	12	3.083
	Contrast Zone (CZ)			Second Periphery (SP)		
3<= Frequency <=10	Physic	3	1.667	Radiotion	4	3.000
	Clean	4	1.750	Particles	8	3.233
	Electricity	8	1.875	Radioactivity	3	3.800
	Angra	4	2.000	Technology	3	4.333
	Gamma Rays	3	2.333	Sun	3	4.667

Table 4. Structure of social representations of students of the Federal University of São Paulo (UNIFESP), based on the inducer term "Chemistry Energy" – PHASE II

	Average Order of Evocation < 2.5			Average Order of Evocation >= 2.5		
	Central Core (CC)			First Periphery (FP)		
Frequency >=10	Atom	16	1.859	Nuclear	11	2,636
	Research	13	2.016	Energy	19	2,895
	Core	14	2.357	Fission	11	3.000
				Radiation	11	3.455
	Contrast Zone (CZ)			Second Periphery (SP)		
3<= Frequency <=10	Chemistry	3	1.000	Uranium	8	2.625
	Study	5	1.800	Neutron	6	2.667
	Alpha	3	2,000	Radioactivity	7	2.714
	Particles	3	2,333	Reaction	9	2.875
	Protons	3	2,333	Fusion	9	3.333
				Technology	3	3.333
				Explosion	3	4.000
				Gamma Rays	3	4.000
				Life	3	4.000
				Reactor	5	4.000

With respect to the inductive term "Nuclear Energy," the word "Bomb," despite not presenting the highest frequency, was readily evoked by many students in the first phase of the study. At the end of the semester, despite the frequency not changing significantly, the term moved from the first quadrant to the second one, in other words, the word was no longer readily evoked. It is worthwhile pointing out that in the second phase of the study, the word that related this technology with "danger" in the first quadrant, and therefore a candidate for the central core was the word "accident," a move that may be associated to the accident in Fukushima nuclear plant, as suggested by the phrases constructed using the evoked words: *"Nuclear energy is obtained in plants where there are risks of accidents, where radiation leaks, such as Chernobyl and Fukushima."*. Another word that registered a high frequency in both phases of the study was "Plant/Reactor," particularly in relation to the energy issue, which is evident in the creation of a phrase made by another student "*Nuclear energy is generated by power plants from reactions, fission*". The elements present in the CC for the inductor term "Nuclear Energy" in both phases of the study do not have a great variety of terms because their frequencies exceed 10 evocations, which in a way may strengthen the possible SR formed in this group, associating nuclear technology mainly to dangerous situations or from the energy standpoint, as shown in the above excerpt. The second quadrant, referring to FP in both phases confirms the possibility that "Bomb" and "Plant/Reactor" may be the core elements of the SR of these students due to the presence of high frequency components such as "Radiation," evoked 32 times, followed by "Hazard/Risk" evoked 24 times in the first phase. Even though a noticeable variation in frequency of these terms was noticed at the end of the semester: "Radiation" evoked 15 times, followed by "Hazard/Risk" evoked 14 times, we cannot claim that there was a significant change in SR among the students.

Another term in the FP, which was one of the first ones evoked by the students in the first phase of the study was "Pollution," even though it is the element with the least presence in this quadrant. This shows that some students have a misconceived idea that the NE generates some kind of pollution in its routine activities. Pollution is an ecological change, in other words, a human-induced change in the relationship between living beings that directly or indirectly harms our life and our wellbeing, such as damage to natural resources, like water and soil, and impediments to economic activities such as fishing and agriculture. Nuclear activity can cause this kind of situation in the event of an accident or incident, but not as a result of its routine activities. It is worth recalling that the students, in addition to evoking the five words asked, had to write a text using these words. The previous assumption was confirmed in these sentences, as follows: *"Nuclear energy is an alternative source that brings much use, but also brings pollution and impurities"; "Nuclear power is very useful but has many risks, impurities and pollution."* After a study of the topic throughout the semester, the word did not appear in the new data collected.

It is interesting to note that elements such as "Renewable" and "Clean" appeared in the third quadrant in the first phase, known as the Contrast Area. This may suggest, according to the article cited in the introduction of this paper [9], that a part of these students seem to have accepted Nuclear Energy as an alternative energy matrix. This was confirmed when they were asked whether Brazil should invest in the development of cleaner and safer nuclear power for future use in its energy matrix (Table 5). However, associating NE to a renewable resource is characterized as a conceptual error, which was corrected during the semester and does not appear in the second phase.

The term "Chernobyl" is present in CZ in the first phase and was evoked very little by the students. It also did not appear in the second phase despite being one of the biggest nuclear technology accidents in the world. The absence of this correlation may arise from two main factors. The first could be the time when the accident occurred (1980s). The participants of the research were mostly born between 1980 and 1990 and this may have interfered in the association. The accident in Goiânia, for example, was not even mentioned (1987). And the second reason would be the lack of discussion regarding this topic in schools.

Table 5. Should Brazil invest in the development of cleaner and safer nuclear power for future use in its energy matrix?

	Strong Option	Priority	Option	Last Option	Should not Invest
First Phase (n=101)	10	7	46	17	14
Second Phase (n=71)	15	9	28	8	6

With regard to the inductive term "Nuclear Chemistry" in the first phase as well as the second phase, the evocations in general for the inductive term showed great variety and are primarily related to atomic structure, as per the content learned in schools.

In the first quadrant of the first phase, the word with the highest frequency and which was readily evoked was "Atoms" with 37 evocations, followed by "Core" with 24 evocations. The term "Chemistry" was readily evoked, as well as "Atoms," despite not having the largest number of evocations. Other evoked elements referred to nuclear technology, examples include the terms "Protons," "Core," "Study" and "Technology." In the CC of the inductive term "Nuclear Chemistry" a great variety of terms were evoked, especially in the first phase, unlike the CC of the inductive term "Nuclear Energy" (Table 1). In the second phase, there is a large reduction of words evoked in the first quadrant, but the word "Atom" keeps popping up, and is therefore a strong candidate for the central core. Another important factor that differs between the two inductive terms, in the first phase as well as the second one, is that for an inductive term referring to "NE" the negative SR of the students is noted, unlike the inductive term "NC," which seems be more connected to terms that refer to science and technology.

For both inductive terms and in both phases of the study, words that could associate this technology to more than the energy issue, for example the healthcare area, are almost nonexistent. The word "Medicine" appears in the Contrast Zone in the first phase for the inductive term “NC” and the word “Health,” for the inductive term “NE,” appears in the second zone, considered less significant.

Lastly, the prior knowledge of these students regarding the nuclear issue was also assessed by asking them to say if the inductive terms "NC" and "NE" were "Very Related," "Somewhat Related," "Little Related" or "Not at All Related" explaining in writing the affinity they believed existed between both. From the written texts, conceptual errors referring to the nuclear topic were perceived. Table 6 below shows a few of these writings.

Table 6. Text written by the students who answered that the terms "NC" and "NE" are "Very Related," "Somewhat Related," "Little Related" or "Not at All Related".

The main one is nuclear energy made from chemical products.
Nuclear chemistry is the study of nuclear energy.
These nuclear chemical reactions can end life on earth.
The study of structure of matter its properties and applications.
The fact that it relates to a core, in this case of some atom in question.
Nuclear Chemistry can generate a "solution" for Nuclear Energy.
Molecular structure / studies about the atomic core.
Physical-chemical processes for the construction of nuclear power.
In Nuclear Chemistry, we study how Nuclear Energy is produced.
I believe that in some cases the chemical reaction may produce nuclear energy.
They are produced by radioactive elements.
For nuclear energy to be produced a chemical reaction is needed.
Nuclear energy comes from changes that occur in the nucleus of atoms, and nuclear chemistry studies these transformations.
They are related due to the types of chemical elements used.
Both arise from the principle of modern energy or through electric waves.

The failure to address the subject of nuclear energy in schools, especially in an interdisciplinary way, leads students to create basic misconceptions related to this science, particularly in reference to the structure of the matter and its transformations in the Nuclear area. This interferes directly in the SR of these students.

This can be remedied if the knowledge gained in the training of these future teachers is transmitted in an interdisciplinary manner and if it critically evidences the benefits and harms of the area, making them reflect, analyze based on reliable information without any distortions.

4. CONCLUSIONS

The students do not know the difference between the terms "Nuclear Chemistry" and "Nuclear Energy" and there are misconceptions related to the two subjects, particularly with respect to atomic structure. This is most likely because the knowledge these students have is basic or none at all as a result of the fact that most have had no contact, or have had minimal contact, with the subject in school.

We verified a wide variety of words evoked for the inductive term "Nuclear Energy," many related to accidents and risks, possibly one of the reasons why these students had a negative SR in relation to the subject. But despite the evocations being negatively related to the topic,

most of the respondents considered it an "Option" or a "Priority" investment in the diversification of Brazil's energy matrix.

A smaller variety of evocations for the inductive term "Nuclear Chemistry" with more students relating this term to atomic structure.

Lastly, a restructuring of SR was noticed at the end of the semester, which indicates that educational training may contribute to a more positive SR and may influence the preference in the energy matrix. However, although we cannot generalize these results as representative of the students of the course, knowing the SR of these students in relation to this subject may help in discovering what obstacles and difficulties they will face in appropriating and incorporating the nuclear issue in the their future teaching practices.

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