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THE DEVELOPMENT OF A MULTISENSORY PROGRAM FOR THE DISSEMINATION OF THE BENEFICIAL APPLICATIONS OF THE NUCLEAR TECHNOLOGY

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ABSTRACT

Despite all peaceful applications of nuclear technology, it is still addressed with prejudice. Prejudices may be explicit (conscious) or implicit (unconscious). However, either explicit or implicit, they interfere with individuals' behavior and attitudes. Prejudices against any theme may be reduced and even reversed by new learning on the theme. Multisensory techniques have proven to make learning richer and more motivating. This work aims to present the development of a multisensory program designed for learning about the beneficial applications of nuclear technology and compare this program to a 12-week traditional teaching program with lecture classes about the nuclear technology. The multisensory program was held at the Instituto de Pesquisas Energéticas e Nucleares (IPEN) for a group of teachers. Assisted tours to the IEA-R1 and to the Centro da Tecnologia das Radiações (CTR) as well as a coffee break serving a variety of commercially-available foods containing irradiated ingredients were part of the multisensory approach. The Implicit Association Test (IAT) was administered before and after the program to identify and measure the implicit associations towards the nuclear technology. This multisensory program was compared to a 12-week traditional teaching program with lecture classes about the nuclear technology held at IPEN. Unlike the multisensory program, the IAT results from the traditional program demonstrated that the lecture classes were not effective for changing the implicit associations. The multisensory program was an effective tool for changing the implicit associations and can be useful for disseminating the beneficial applications of the nuclear technology.

1. INTRODUCTION

Since the discovery of nuclear fission in the 30s, the peaceful applications of nuclear technology have benefited several fields. Despite all benefits that result from the peaceful uses of nuclear technology, its public acceptance is reduced and it is still addressed with prejudice. One main reason for prejudice against nuclear technology is the lack of assertive information on its risks and benefits [1]. Furthermore, due to nuclear accidents in history, people retain their fears of the potential for nuclear energy to cause widespread damage or disaster [2].

Prejudice regarding any theme may be explicit – at the conscious level – or implicit – operating outside awareness; however, either explicit or implicit, prejudices impose barriers on individuals and interfere with their attitudes and behavior [3, 4]. Concerning nuclear technology, holding prejudice against it may interfere with authorities' decision on the development of new technology.

The field of educational neuroscience has developed several types of implicit association tests to assess the implicit prejudices [5-7]. The Implicit Association Test (IAT) is a reliable tool used worldwide to measure implicit attitudes toward discriminatory behaviors [8,9]. Since prejudices are reported in the nuclear energy education scenario, implicit measurement techniques can be an effective tool to identify and measure prejudices against nuclear technology.

The literature demonstrates that implicit prejudices may be avoidable, reduced and even reversed [3,4]. Thus, implicit prejudices against the use of nuclear technology may be reduced or even extinguished by assertive and balanced information on its benefits, safety, potential risks, and peaceful applications in several fields.

Modern education includes an efficient partnership with neurosciences, which have given consistent scientific support for educational practices. One of these current educational practices consists of a multisensory approach. Multisensory is a term used to refer to any learning activity that combines two or more sensory strategies to acquire or express information. The results reported in the literature indicate that multisensory techniques have proven to make learning richer and more motivating [10-13].

This work aims to present the development of a multisensory program designed for learning about the beneficial applications of nuclear technology and compare this program to a 12-week traditional teaching program with lecture classes about the nuclear technology.

2. RESEARCH DEVELOPMENT

The Implicit Association Test (IAT) was used in this study to measure the implicit associations of the participants towards the use of the nuclear technology. The IAT assumes that the more closely related the objects and attributes are, the stronger the implicit attitude is. The IAT is a reliable implicit memory test aimed at measuring associative knowledge [14].

Due to the fact that the IAT is a computer-based test, the *Free*IAT software was used to administer the IAT proposed by this study [15].

2.1 The *Free*IAT software

The *Free*IAT is a free, open-source, and highly customizable software used to administer the Implicit Association Test [15]. By following the steps provided by the *FreeIAT*, a customized IAT was built aiming to compare the implicit associations of participants towards nuclear technology [16].

The design of the IAT proposed for this study consisted of selecting a set of words related to nuclear technology and oil and a set of positive and negative words. The words related to nuclear technology were: *fission, radiotherapy, radioisotopes, neutron, uranium, Angra 2,* *radiation, reactor, radiopharmaceuticals,* and *plutonium*. The words for “oil” were: *gasoline, kerosene, asphalt, pre-salt, platform, Petrobrás, pipeline, drilling, diesel,* and *fossil.* The positive words were: *peace, safety, protection, healthy, and joy.* The negative words were: *tragedy, horrible, bad, harmful, and sadness.*

The IAT procedure has five steps. The participants see the stimuli (words) that are presented sequentially in the center of the computer screen and are asked to respond as fast as possible by pressing the “E” key if the word belongs to the category on the left and the” I” key if the word belongs to the category on the right. The IAT effect is calculated by using latency data from steps 3 and 5 [14].

In order to demonstrate the steps of the IAT designed for this research, one example of possible association will be provided in Figures 1 to 4.

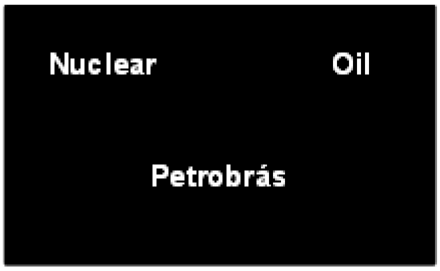

Figure 1: The concept dimension

Figure 2: The attribute dimension

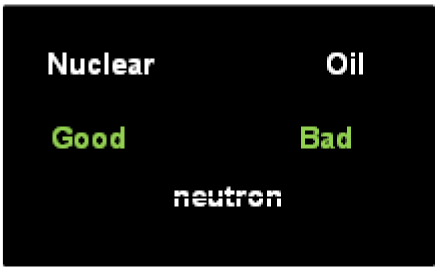

Figure 3: Concept-attribute pairing

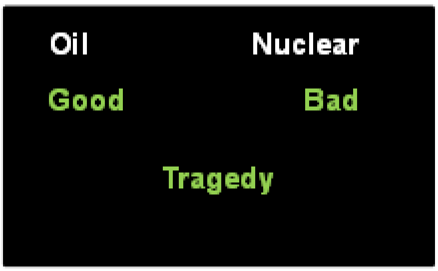

Figure 4: Categories are combined in opposite way

A pre-test with nuclear specialists was administered to check the consistency of the IAT proposed for this study. The Cronbach´s alpha was applied to measure the reliability of the test. The value of alpha was .869, suggesting that the items had good internal consistency [17].

2.2 The multisensory approach

The development of the methodology proposed in this paper was based on a multisensory approach, terminology often used to describe strategies that involve activities integrating two or more sensory modalities in order to acquire or express information [18]

Studies conducted in several countries have shown that the use of different sensory modalities has a positive effect on learning, resulting in improved cognitive memory, faster motor responses and increased perceptual sensitivity [11]. According to the literature, the use of multiple sensory modalities provide real learning as it promotes the formation of neural networks through new brain connections [19-23].

A 5-hour multisensory program for a group of science teachers was designed and held at the *Instituto de Pesquisas Energéticas e Nucleares* (IPEN). The science teachers were chosen for this program because of their educational role regarding the use of nuclear science and technology. Thirty-three Brazilian science teachers, being 13 male and 20 female, aged between 21 and 62 years, attended the program.

In order to verify the impact of the program on the associations of the science teacher towards nuclear technology, the Implicit Association Test (IAT) was administered at the beginning and at the end of the program. The pre- program and post-program IAT results were compared.

Upon arrival at the auditorium of the Nuclear Engineering Center (CEN) at IPEN, the teachers were greeted with a breakfast including a variety of commercially-available foods containing irradiated ingredients such as: Club Social Pizza, Torcida brand snacks (bacon flavor and onion and parsley flavor), as shown in Figure 5.

Figure 5: Breakfast served to the science teachers

Subsequently, the first IAT test was administered to the teachers to identify and measure their implicit associations towards nuclear technology (Fig. 6).

Figure 6: The IAT administration

Immediately after the administration of the IAT, the teachers were taken to an assisted visit to the IEA-R1 research reactor at the Nuclear Research Reactor Center (CRPq) and the Radiation Technology Center (CTR), both located on the IPEN campus (Fig. 7, 8). Each visit lasted about an hour and thirty minutes.

Figure 7: Visit to IEA-R1 (CRPq)

The visit to the IEA-R1 was assisted by an expert operator who led the teachers to the various sectors of the reactor building, explained its operation, safety standards, applications, maintenance, and answered questions of the teachers.

Figure 8: Visit to the Radiation Technology Center (CTR)

The visit to the CTR was also assisted by an expert. The teachers visited the facilities and were provided with information on the various applications of radiation technology (in food, brachytherapy seeds, rubber, among others), and on radioisotope production. They also had the opportunity to clarify doubts and curiosities on the subject.

After the assisted tours, the teachers returned to the CEN auditorium, were served another coffee break with the same products served on their arrival. Shortly after the coffee break the teachers watched a short PowerPoint presentation with photos of the places they visited (CRPq and CTR) and also listened about the products served at the coffee break, having the opportunity to read the packaging labels with information about the irradiated ingredients.

The IAT was again administered to assess whether there were changes in the implicit associations of the science teachers after the multisensory program, which lasted 5 hours. The IAT results from the multisensory program were compared to the IAT results from 12-week traditional teaching program with lecture classes about the nuclear technology held at IPEN. The comparison between both programs will be presented in item 3.

2.3 The traditional teaching program

Students from the Graduate Program in Nuclear Technology at IPEN are supposed to attend four specific subjects in the following sequence: 1) TNA5780 - Fundamentals of Nuclear Technology - Nuclear Physics and its Applications; 2) TNM5788 - Fundamentals of Nuclear Technology - Materials and Fuel Cycle; 3rd) TNR5764 - Fundamentals of Nuclear Technology Reactors; 4th) TNA5781 - Fundamentals of Nuclear Technology - Radiological Protection.

The 12-week traditional teaching program aims to provide students with the basics of the nuclear field. For most students, this is the first contact with the nuclear field due to the absence of related topics in the undergraduate program. Each subject is given in a lecture format class. The 3-hour-classes are taught on two days of the week (Tuesdays and Thursdays), for three weeks in a row, a total of 45 hours each.

In order to verify the impact of the 12-week traditional teaching program on the associations towards nuclear technology, the Implicit Association Test (IAT) was administered to 16 students, 11 males and 5 females, aged between 21 and 64 years, at the beginning (first day of class) and at the end of the program (final class, after 12 weeks).

The pre- program and post-program IAT results from the traditional program were compared and will be presented in item 3.

3. RESULTS AND DISCUSSION

In order to verify the impact of both programs on the implicit associations towards nuclear technology, the Implicit Association Test (IAT) was administered at the beginning and at the end of each program.

3.1 The 5-hour multisensory program: pre-program and post-program IAT results

The IAT pre-program results demonstrated that 30,3% of the science teachers had positive implicit association towards nuclear technology, 36,4% had negative associations towards it and 33,3% were neutral, as shown in Figure 9.

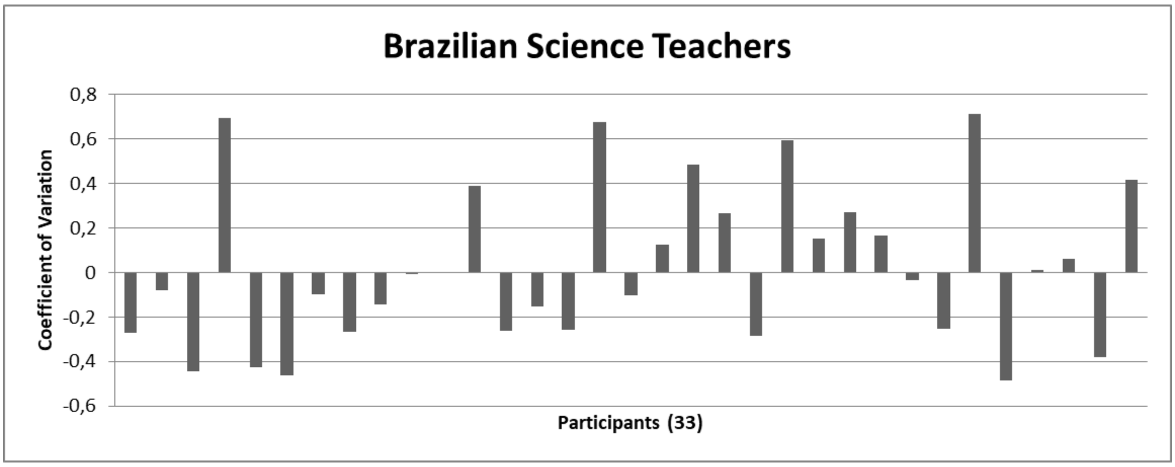

Figure 9: Implicit associations towards nuclear technology

At the end of the multisensory program the IAT was administered again to the science teachers in order to assess and identify changes in the implicit associations towards nuclear technology. The post program results indicated changes in the implicit associations of the sciences teachers towards nuclear technology and prejudice reversal.

The IAT post-program results demonstrated that 57,6% of the science teachers had positive implicit association towards nuclear technology, 12,1% had negative associations towards it and 30,3% were neutral.

In Table 1 the comparative results from the administration of the IAT before and after the multisensory program are shown.

Table 1: The comparative results from the administration of the IAT

	Positive associations towards nuclear technology		**Negative associations towards nuclear technology**		**neutral**	
Participants (n=33)	Pre-program	Post- program	Pre-program	Post- program	Pre-program	Post- program
	30,3 %	57,6%	36,4%	12,1%	33,3%	30,3%

The percentage of positive associations towards nuclear technology almost doubled after the multisensory program. Concerning the negative associations, there was a significant difference between the initial and final values. The difference can be explained by the fact that the subjects who initially had negative implicit associations had changes after the program. Some of them demonstrated positive associations and some became neutral.

Although the percentages for neutrality remained similar, they do not refer to exactly the same participants, but are due to changes in the scores of participants, who were initially neutral but had positive associations after the multisensory program, and participants, who initially had negative associations towards nuclear technology but at the end, were neutral or even positive.

In order to verify the degree of reliability of the results indicated by the descriptive statistics, the Student t test was applied to this group, and the hypotheses studied were:

1) H0, the group of science teachers had no changes in implicit associations after the multisensory program (T1 = T2), with $\rho > 0.05$;
2) H1, the group of science teachers had changes in implicit associations after the multisensory program (T1 ≠ T2) with $\rho \leq 0.05$.

Given the 95% confidence interval a value of $t(33) = -3.513$, $\rho = 0.001$ was observed, indicating that the mean of T1 is different from T2 and therefore the null hypothesis (H0) is rejected. These statistically significant results confirm the change in implicit associations of science teachers after the multisensory program

3.1 The 12-week traditional teaching program: pre-program and post-program IAT results

The IAT pre-program results demonstrated that 62,5% of the students had positive implicit association towards nuclear technology, 25% had negative associations towards it and 12,5% were neutral, as shown in Figure 10.

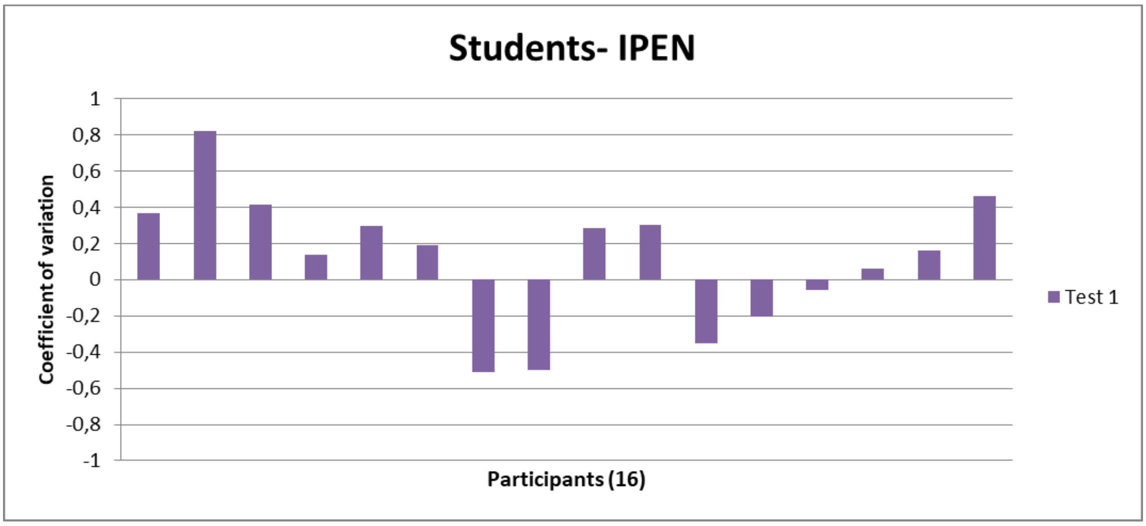

Figure 10: Implicit associations towards nuclear technology

At the end of the traditional program the IAT was administered again to the students in order to assess and identify changes in the implicit associations towards nuclear technology.

In Table 2 the comparative results from the administration of the IAT before and after the traditional program are shown.

Table 2: The comparative results from the administration of the IAT

	Positive associations towards nuclear technology		**Negative associations towards nuclear technology**		**neutral**	
Participants (n=16)	Pre-program	Post- program	Pre-program	Post- program	Pre-program	Post- program
	62,5 %	37,5%	25%	12,5%	12,5%	50%

After 12 weeks, both the percentage of positive associations towards nuclear technology and the negative associations decreased, while the percentage of neutral associations increased, from 12, 5% to 50%.

In order to verify the degree of reliability of the results indicated by the descriptive statistics, the Student t test was applied to this group, and the hypotheses studied were:

1) H0, the group of students had no changes in implicit associations after the 12-week program (T1 = T2), with $\rho > 0.05$;
2) H1, the group of students had changes in implicit associations after the 12-week program (T1 ≠ T2) with $\rho \leq 0.05$.

Given the 95% confidence interval, a value of t (16) = 0.458, ρ = 0.654 was observed, indicating $\rho > 0.05$. The mean of T1 = T2; therefore, the null hypothesis (H0) is accepted.

Those statistical results demonstrate that there were no changes in the implicit associations of graduate students after 12 weeks of traditional teaching with lectures on various aspects related to nuclear technology.

The lecture-based model of classes dates back to the Middle Ages and is still the most widely used method of instruction. This instructional method represents the oral tradition, since the teacher delivers most information to students verbally. The literature reports that in this traditional model, students have shown less learning success, less innovation skills, and tend not to build deep knowledge of critical concepts [24-27].

Unlike the traditional teaching program, the IAT results obtained at the beginning and at the end of the 5-hour multisensory program demonstrated that this method was effective for changing previous implicit associations towards the nuclear technology.

According to literature, multisensory experiences causes the formation of wide neural networks, enhances learning, improves cognitive memory, and are more efficient than unisensory stimuli [10, 12, 19, 20, 22, and 23].

4. CONCLUSIONS

The results from the IAT administered at the beginning and at the end of the traditional teaching program demonstrated that the lecture classes were not effective for changing the implicit associations of the students towards the nuclear technology.

The results from the IAT administered before and after the 5-hour multisensory program designed for this study demonstrated statistically significant changes in the implicit memory of the science teachers towards the nuclear technology.

The multisensory program has proven to be an effective tool, able to produce changes in implicit associations and can be useful for disseminating the beneficial applications of the nuclear technology.

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