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The Use of Virtual Reality as an Aid Tool in the Implementation of a Radiopharmacy Center in a Nuclear Medicine Service

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ABSTRACT

Radiopharmaceutical preparations must follow the parameters of quality, efficacy and safety (pharmaceutical and nuclear), complying with all the requirements established in good manufacturing practices, guaranteed by the physical structure, layout, safety and radiological protection, which are also fundamental for the correct flow. is followed by excellence in service operation. One of the main problems related to the flow of radiopharmaceuticals is exposure to ionizing radiation. Factors like this corroborate the need for training that simulate real situations, however, situations like this are limited due to the risk of exposure. The objective of the article is to propose and evaluate the use of virtual reality (VR) technology for training and qualification of professionals in a radiopharmacy. The applied methodology was divided into four stages, in the first one the norms and regulations referring to the Nuclear Medicine Service and international recommendations of the International Atomic Energy Agency (IAEA) were analyzed in detail, in the second one visits were made to public and private hospitals in Rio de Janeiro that present the medicine service, in the third stage the virtual environment (simulator) was built and in the fourth stage strategies were proposed for carrying out the training. The use of a virtual simulator allowed the creation of a realistic environment, where the user can navigate and manipulate objects in the virtual world. Therefore, it is expected that this tool can help in the planning and training of radiopharmacy professionals. As a result, we have created a visual environment to plan Radiopharmacy training. It is understood that the developed application serves as subsidies for techniques in the training of professionals who work in radiopharmacy.

Keywords: **Radiopharmacy; Nuclear Medicine; Radiopharmaceuticals; Virtual Reality.**

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1. INTRODUCTION

Nuclear medicine began with the great discoveries about natural radioactivity by the French physicist Henri Becquerel, in 1896. This modality encompasses several points that are related to actions involving radiopharmaceuticals in the administration, for diagnostic and therapeutic purposes. Being an area of medical specialty that uses in its practice radioisotopes that are responsible for emitting radiation to obtain the image in diagnostic terms or for therapeutic applicability [1].

In radiopharmacy we have the small-scale preparation of radiopharmaceuticals, carried out under a license, which complies with national standards and regulations. It is scientifically recognized as the essential subspecialty for Nuclear Medicine (NM), however in the absence of radiopharmaceuticals, procedures such as radiodiagnosis or radiotherapeutics could not be performed [2]. In 2009, National Health Surveillance Agency (ANVISA) released the first resolution (Collegiate Board Resolution - RDC Nº 63/2009) on radiopharmaceuticals, enacting them as:

"Radiopharmaceuticals are pharmaceutical preparations with diagnostic or therapeutic purposes which, when ready for use, contain one or more radionuclides. They also include non-radioactive components for labeling and radionuclides, including components extracted from radionuclide generators" [3].

As described in Resolution No. 656 of May 24, 2018, it is the duty of the pharmaceutical professional to be responsible for the entire process involving the radiopharmaceutical. Being of paramount importance, the training and qualification of professionals in a radiopharmacy, in accordance with the rules and regulations referring to the nuclear medicine service (NMS) published by the National Health Surveillance Agency (ANVISA), National Commission of Nuclear Energy (CNEN), and international recommendations by the International Atomic Energy Agency (IAEA). In this scenario, virtual environments have wide applicability in simulations, which in real training can be costly, time-consuming, and dangerous [4, 5, 6, 7].

With virtual reality (VR), we can simulate hypothetical situations, of any nature, without any exposure to ionizing radiation, public individuals and the environment. We can consider the creation of this VR environment as a new technique for better learning, obtaining great advantages over traditional methods [4, 5, 7]. Therefore, the objective of this article is to propose and evaluate the use of a virtual reality (VR) simulator, to be applied in training and qualification of professionals who are involved in the processes of a radiopharmacy, which involves direct and indirect contact with ionizing radiation from in accordance with the rules and regulations in force that refer to the SMN.

2. THEORETICAL FOUNDATION

2.1. VIRTUAL REALITY

Virtual Reality (VR) has been gaining ground in the teaching scenario, for practices in the health area, for medical training in surgical simulations, to improve professional performance and the quality of the service provided. In addition to practical learning, VR can bring professionals the exchange of knowledge with others, as it becomes an interactive environment capable of transferring data and skills, in this way the professional acquires practice and knowledge, while the developer can apply all experience to this experience [8].

The applicability of VR is gaining more and more space and it is configured as a new method of support for learning and training and with this new way of teaching subjects were linked to new discussions and unprecedented challenges, with this learning system we can gain allies in teaching, and with the insertion of technology in basic practices, it greatly facilitated the gain in quality of training. Immersion in VR will provide the professional with three-dimensional scenarios that have unique possibilities for presenting situations and where some of these situations could cause damage to the professional, if this real training was necessary, also applying representation of objects, layout in environments, knowledge of new areas, between others. Lessons using VR are activities that reduce financial expenses and save physical and material resources [8, 9].

The use of VR in radiopharmacy can be a great option for producing training for the teams that will be placed to follow the flow during the workdays with VR being used, we can classify the training with a percentage of greater quality and safety, if compared with other types of training used.

The creation of a virtual environment (VE) of a radiopharmacy exemplifies methods and materials, in addition, we can create a place where the individual can use equipment, that is, in addition to demonstrating radiopharmacy, we can create practices for using the equipment, in this way is analyzed and quantified accident events would be reduced by a large number.

2.2. NUCLEAR MEDICINE

Medical practice in Nuclear Medicine (NM) is a specialty that uses highly safe methods that generally do not cause pain to the patient being treated. MN methods are also mostly non-invasive procedures and even though they have a relatively low cost for the institution to provide information that other diagnostic tests would not be able to, using open sources of radionuclides. Generally, the uses of radioactive materials are to be administered in vivo, by various routes, such as venous, oral, inhaled or subcutaneous, and these, after administration, present a distribution to specific organs or cell types, with no risk of allergic reactions. This distribution can be expanded by various characteristics of the radioactive element itself. And at other times it is linked to another chemical group, forming a radiopharmaceutical with affinity for certain tissues. [10].

2.3. RADIOPHARMACEUTICALS

The radioactive compounds that are radiopharmaceuticals can be used in the practice of NM and for the purpose of diagnosing diseases. These are used in a medical specialty that received the name of Nuclear Medicine, precisely because they work using radiopharmaceuticals, or rather, called radioactive drugs. [2, 11].

According to Oliveira, et. al (2008) radiopharmaceuticals are compounds that do not have pharmacological action, and that have a radionuclide in their composition, and that NM makes use of them to diagnose pathologies and for therapy of some of these. So what is really used for therapy is the ionizing radiation of the radionuclide, this effect on the target that can be tissues or organs causes the destruction of tumor cells, but on the other hand the destruction ends up causing the loss of cells that would not be radiation targets, then one should seek to use the most correct and selective therapy possible to minimize side effects, which are harmful to the patient [12].

In the use of radionuclides for diagnosis, radioactive elements with a short half-life, low energy and lower activities are used, to minimize the dose due to radiation, and whose emitted photons have enough energy to be detected externally, after crossing the body of the patient.In the therapy, radiopharmaceuticals, alpha and beta emitters are used in higher activities, providing greater effectiveness of the biological damage along the trajectory of the particle in the target tissue, that is, increasing the probability of elimination of undesirable cells [13]

3. MATERIALS AND METHODS

The methodology applied for the development of this article was divided into four stages. In the first stage, the standard and recommendations regarding the current legislation, which specify the requirements for the practice of NM, were analyzed in detail. In the second stage, field research was carried out in public and private hospitals in Rio de Janeiro, which have the Nuclear Medicine Service (NMS). In the third stage, the virtual environment (simulator) was built using virtual reality tools, from the Institute of Nuclear Engineering (IEN), located on Ilha do Fundão, Rio de Janeiro, Brazil. Properties such as immersion, interaction and presence make VR an interesting application tool for the health area, capable of reproducing real situations in safe virtual environments. Finally, the fourth step with the creation of this VR environment, brings together attributes that make the tool ideal for multiple situations and the context for training, as they aim to add knowledge and develop skills, obtaining great advantages over traditional methods, making it possible to evaluate user actions, identifying successes, failures and difficulties.

3.1. DOCUMENTAL AND BIBLIOGRAPHICAL RESEARCH

A bibliographical survey of the scientific literature was carried out and later the rules and legislation in force that exemplify and specify the requirements for the practice of nuclear medicine, referring to the use of ionizing radiation, were analyzed. National Nuclear Energy Commission (CNEN):

- Standard CNEN NN 3.01 Basic Radiation Protection Guidelines.
- Standard CNEN NN 3.05 Radiation protection and safety requirements for nuclear medicine services.
- Standard CNEN NN 8.01 Management of radioactive waste with low and medium levels of radiation.

And for practices related to health, such as nuclear medicine, one should also take into account the provisions of the collegiate board of the National Health Surveillance Agency (ANVISA):

- RDC ANVISA No. 38 Installation and operation of "in vivo" nuclear medicine services" [14];
- RDC ANVISA No. 50 Technical regulation for planning, programming, elaboration and evaluation of physical projects of health care establishments;
- RDC ANVISA No. 63 Good manufacturing practices for radiopharmaceuticals;

It was also analyzed the international recommendations published by the International Atomic Energy Agency (IAEA):

- Radiation protection and safety of radiation sources: International Basic Safety Standards. (BSS) - International Atomic Energy Agency, [15];
- Applying radiation safety standards in nuclear medicine - International Atomic Energy Agency, [16].

3.2. FIELD RESEARCH

Initially, the dissertation work "Unification of radiological protection parameters for training radiopharmacy professionals in Nuclear Medicine services" was used as a basis, authored by student Juliane de Sá Carvalho in March 2018 [17]. This work unified parameters referring to the activities carried out in a radiopharmacy center.

Field research was carried out in Nuclear Medicine Services, which are references in the State of Rio de Janeiro, in the following hospitals:

- Clementino Fraga Filho University Hospital (HUCFF-UFRJ)
- Copa Star Hospital

3.3. RADIOPHARMACY PROCESS MODEL

It is extremely important that the complete flow of radiopharmaceuticals within the facilities of a radiopharmacy is fully elucidated, so that there is a guarantee of the quality of the radiopharmaceutical and the safety of all those directly or indirectly involved in the process, and in view of this need, the Business Process Management (BPM) method for modeling processes.

Is an adaptive management approach, developed with the purpose of systematizing and facilitating complex individual organizational processes, inside and outside companies in a simple and clear way.

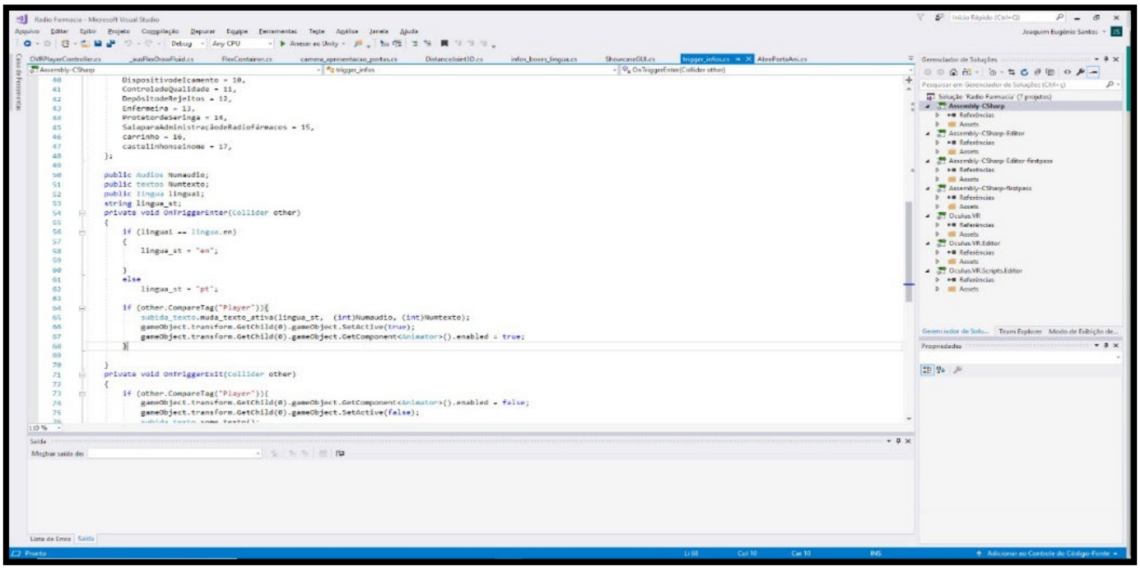
3.4. CONSTRUCTION OF THE RADIOPHARMACY VIRTUAL MODEL

The requirements listed below describe the characteristics and functionalities necessary for the development of the virtual environment and the modeling of scenarios and objects, this stage had the essential contribution of the development team of the Virtual Reality Laboratory (LabRV – located at IEN).

3.4.1. MICROSOFT VISUAL STUDIO

Microsoft Visual Studio (FIGURE 1) is an integrated development environment from Microsoft for software development that meets the most diverse objectives and has the possibility of exporting solutions to multiple platforms using different programming languages.

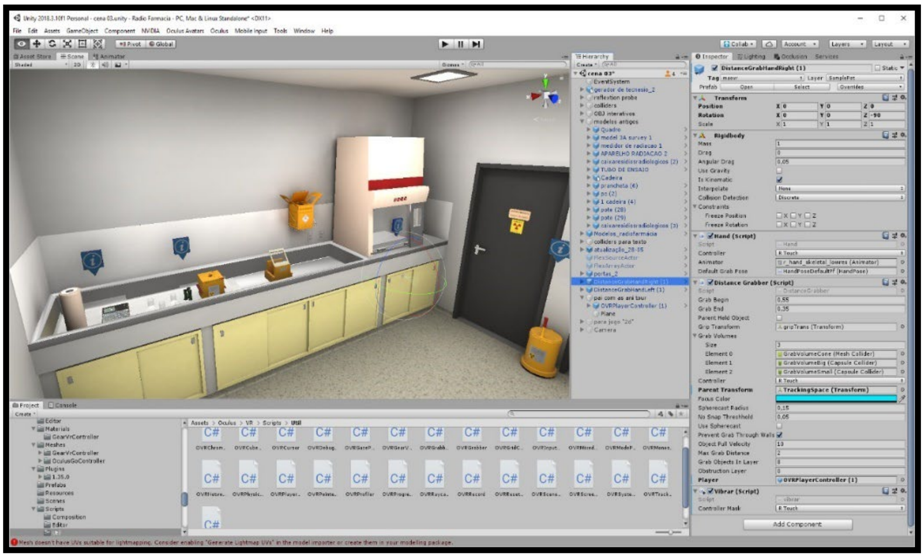
Figure 1: *Microsoft Visual Studio Development Environment*



3.4.2. Unity

It is a graphics engine used for electronic games and simulators of three-dimensional environments in general (FIGURE 2). It has advanced development tools supporting several different Application Programming Interfaces (APIs) and integrations with codes written in Visual Studio or MonoDevelop.

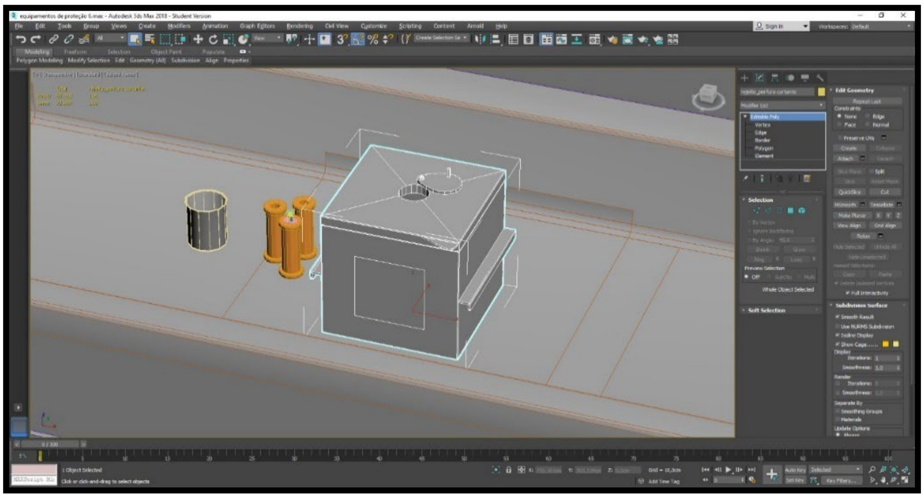
Figure 2: *Main Interface of the Radiopharmacy Project*



3.4.3. 3D Studio Max

3Ds Max (FIGURE 3) is a three-dimensional modeling program that allows rendering of images and animations. Being used in animation film production, 3D game character creation, television vignettes and commercials, electronic mockups and in the creation of any virtual world.

Figure 3: *Graphic Interface of the 3Ds Ma Three-Dimensional Modeling Programx*



4. RESULTS

4.1. APPLICATION OF THE METHODOLOGY

After the previous steps, detailed analysis of the recommendations and norms referring to the NMS and the creation of the virtual environment (simulator) in radiopharmacy, adopting VR techniques that were carried out for assembly. We present as a proposal the use of the tool developed for training purposes, the virtual environment will allow replicating the ideal needs for the implementation of a radiopharmacy, presenting layout, detailing of the physical space and infrastructure, providing the appropriate physical conditions to carry out training with an emphasis on radiological safety and protection, especially in those procedures that involve risk to professionals, such as those associated with occupational exposure to ionizing radiation.

One of the main problems in a radiopharmacy is related to the flow of radiopharmaceuticals, which implies exposure to ionizing radiation. In view of the above, the virtual environment developed follows a script exemplifying each step of the flow of a radiopharmacy in a nuclear medicine service, below we will show some images of steps regarding the use of virtual reality for this implementation.

4.1.1 EQUIPMENT AND RADIOLOGICAL PROTECTIONCONCLUSION

In the gowning and radiological protection room (FIGURE 4), we store all the monitoring instruments that the occupationally exposed individual (OEI), referring to radiological protection, must use during the entire period of work, mandatorily, such as: the dosimetric pen or single monitor. It is also of paramount importance the proper use of PPE's such as: shoe, cap, apron and gloves.

Figure 4: *Clothing and Radiation Protection*

4.1.2 MULLER GEIGER COUNTER

Used to detect the presence of radioactivity. Upon receipt, we need to measure its exposure (measure the shielding), before storage, checking that it is in accordance with the sheet that comes with the product. The people involved must also undergo continuous monitoring, including hands, feet and clothing (FIGURE 5).

Figure 5: *Geiger Muller counter*

4.1.3 LAMINAR FLOW HOOD

To minimize the professional's exposure to ionizing radiation emitted by radiopharmaceuticals, manipulation must be performed in an exclusive area and in a laminar flow hood, always using appropriate instruments such as: tweezers, fountain holders and lead castets (FIGURE 6).

Figure 6: *Laminar Flow Chapel*

4.1.4 STOCK / STOCK

Radiopharmaceuticals and products used in their preparation must be stored separately, in an exclusive place, to preserve safety, quality and meet radioprotection requirements (FIGURE 7).

Figure 7: *Inventory / Storage*

4.1.5 SOURCE STOCK

Place for temporary storage of unused radiopharmaceuticals, it must be a place that is easy to clean and that contains safety devices for correct storage, it must have adequate shielding for Nuclear Medicine services (FIGURE 8).

Figure 8: *Source Stock*

4.1.6 NUCLEAR WASTE REPOSITORY

Materials stored in the nuclear waste repository must be identified in categories according to physical state, type of radiation, concentration and exposure rate. These materials must be segregated and stored in the same place where they were generated for a sufficient time so that their activity is equivalent to that of common waste (FIGURE 9).

Figure 91: *Nuclear Waste Repository*

5. DISCUSSION

After using the tool, users were invited to answer a questionnaire, with the purpose of evaluating the opinion of professionals, who work in the nuclear area, about the use of a virtual environment in radiopharmacy as an auxiliary tool, in the establishment of strategies for training and qualification professional.

The questionnaire with thirteen questions was divided into three groups, they are:

- The first group related to questions 1, 2 and 3 deals with the adherence of the model to current legislation, with the aim of ensuring that the virtual environment fully respects the laws and regulations related to the nuclear medicine service;
- The second group related to questions 4, 5 and 7 focuses on the methodology that will be applied in training;
- The third group related to questions 6, 8, 9, 10, 11, 12 and 13 deals with the viability of the virtual model for simulation and training.

To validate the developed tool, it was necessary to organize a presentation with a group of professionals, who have relevant training in the area or who work in the nuclear segment. The participating professionals were divided into three groups, the first group is composed of technical professionals in the nuclear area who work directly in radiopharmacies, with the manipulation of radioisotopes; the second group human/system interface of the IEN was chosen with the purpose of evaluating the tool, as they have knowledge in the use of systems and in human cognition; the third group are employees of the Division of Safety and Radiological Protection (DISPR) of IEN, who carried out an evaluation from the point of view of radiological protection, of the virtual model of a radiopharmacy.

First, a brief introduction to the objectives was presented, with the main guidelines, standards and current legislation, which are applied in a real radiopharmacy and the good practices pertinent to NM. Subsequently, in association with the virtual environment, a script was presented where the environments that make up the flow of the radiopharmaceutical were described, from receipt to administration to the patient in detail.

Then, the professionals, individually, were guided by the development team on how the model (simulator) works and on the immersive experience in the virtual environment. Initially, they followed the pre-established script, previously exemplified in the slides, and at the end of the application it was placed for free experimentation. After using the tool, professionals were invited to answer the evaluation questionnaire.

As a result of this work, a virtual environment was built to simulate the process of a radiopharmacy, adopting virtual reality techniques as an auxiliary tool for training. Training can be carried out countless times and learning can be done in stages, facilitating the absorption of content by professionals, until the required skills are acquired and the information is assimilated correctly.

5.1.EVALUATION BY THE LIKERT METHOD

For the analysis according to the Likert scale [18], 3 groups were analyzed:

- For the first group of Nuclear Area Technicians, responses were obtained from 7 questionnaires whose results are shown in table 1.
- For the second group of IEN Human Interface / System, answers to questions 1 to 6 were obtained from 3 questionnaires and from questions 7 to 13 responses to 4 questionnaires were obtained, the results of which are shown in table 2.
- For the third IEN Radiological Protection group, responses were obtained from 7 questionnaires whose results are shown in table 3.

For these tables, the following criteria are valid for the answers:

- DI: I completely disagree;
- DP: partially disagree;
- NCND: I do not agree nor disagree;
- CP: partially agree;
- CI: I completely agree.

Table 1: *Questionnaire Result – Group 1 – Nuclear Area Technicians*

Question Number / Answers	DI	DP	NCND	CP	CI
1	0	0	0	3	4
2	0	0	0	2	5
3	0	0	0	2	5
4	0	0	0	2	5
5	0	0	0	5	2
6	0	0	0	3	4
7	0	0	0	1	6
8	0	0	0	0	7
9	0	0	0	0	7
10	0	0	0	3	4
11	0	0	0	1	6
12	0	0	0	2	5
13	0	0	0	0	7

Table 2: *Questionnaire Result – Group 2 – IEN Human / System Interface*

Question Number / Answers	DI	DP	NCND	CP	CI
1	0	0	2	0	1
2	0	0	1	0	2
3	0	0	1	0	2
4	0	0	0	1	2
5	0	0	1	0	2
6	0	0	0	1	2
7	0	0	0	0	4
8	0	0	0	0	4
9	0	0	0	0	4
10	0	0	0	0	4
11	0	0	0	1	3
12	0	0	1	0	3
13	0	0	0	0	4

Table 3: *Questionnaire Result – Group 3 – IEN Radiological Protection*

Question Number / Answers	DI	DP	NCND	CP	CI
1	0	0	2	1	3
2	0	1	1	2	2
3	0	2	0	3	2
4	0	1	0	2	4
5	0	0	0	5	2
6	0	0	0	3	4
7	0	0	1	1	5
8	0	0	1	0	6
9	0	0	0	1	6
10	0	0	0	0	7
11	0	0	1	1	5
12	0	0	0	1	6
13	0	0	0	0	7

The graphs resulting from the Likert scale for the three evaluated groups are shown below, as follows: Group 1 – Technicians in the Nuclear Area (FIGURE 10), Group 2 – Human Interface / IEN System (FIGURE 11) and Group 3 – Radiological Protection of the IEN (FIGURE 12).

Figure 10: *Likert Method Result Chart – Group 1 – Nuclear Area Technicians*

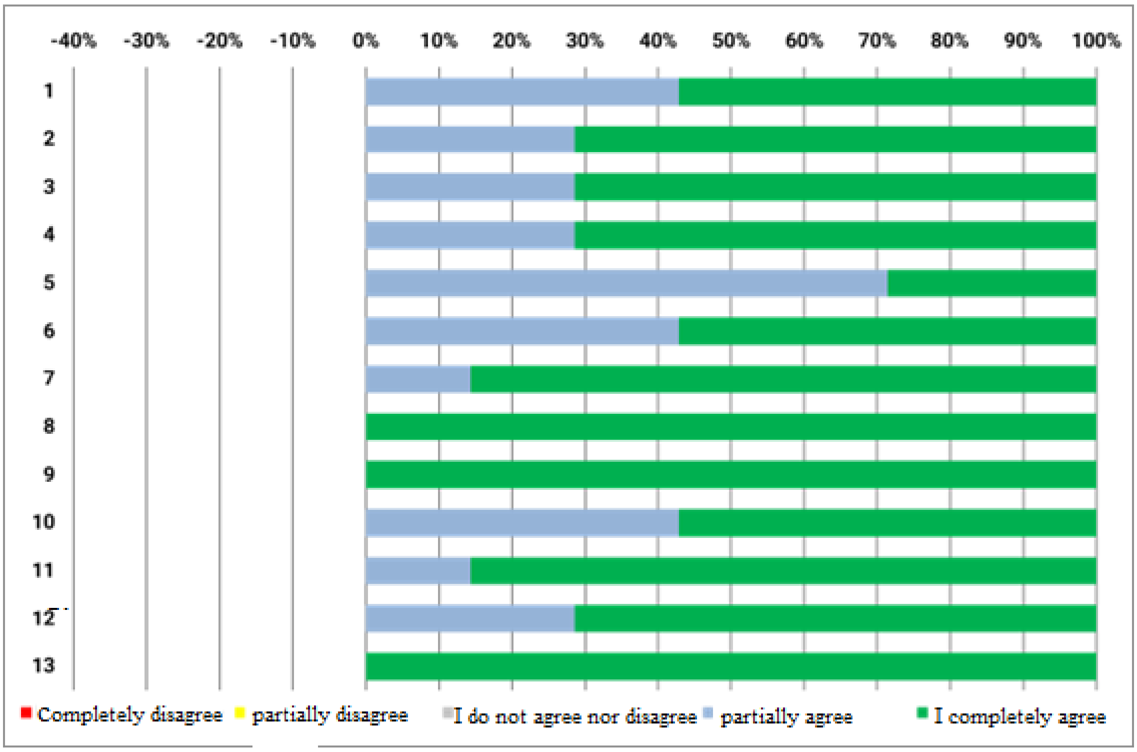


Figure 11: *Graph of the Result of the Likert Method – Group 2 – Human Interface/IEN System*

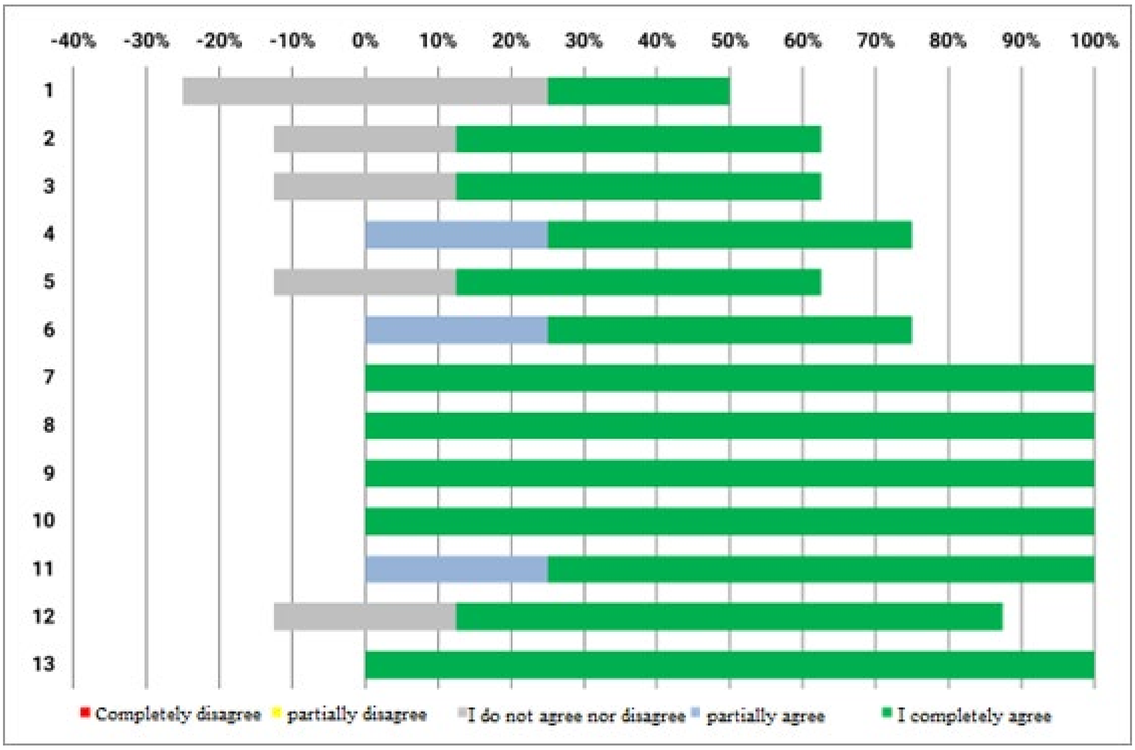
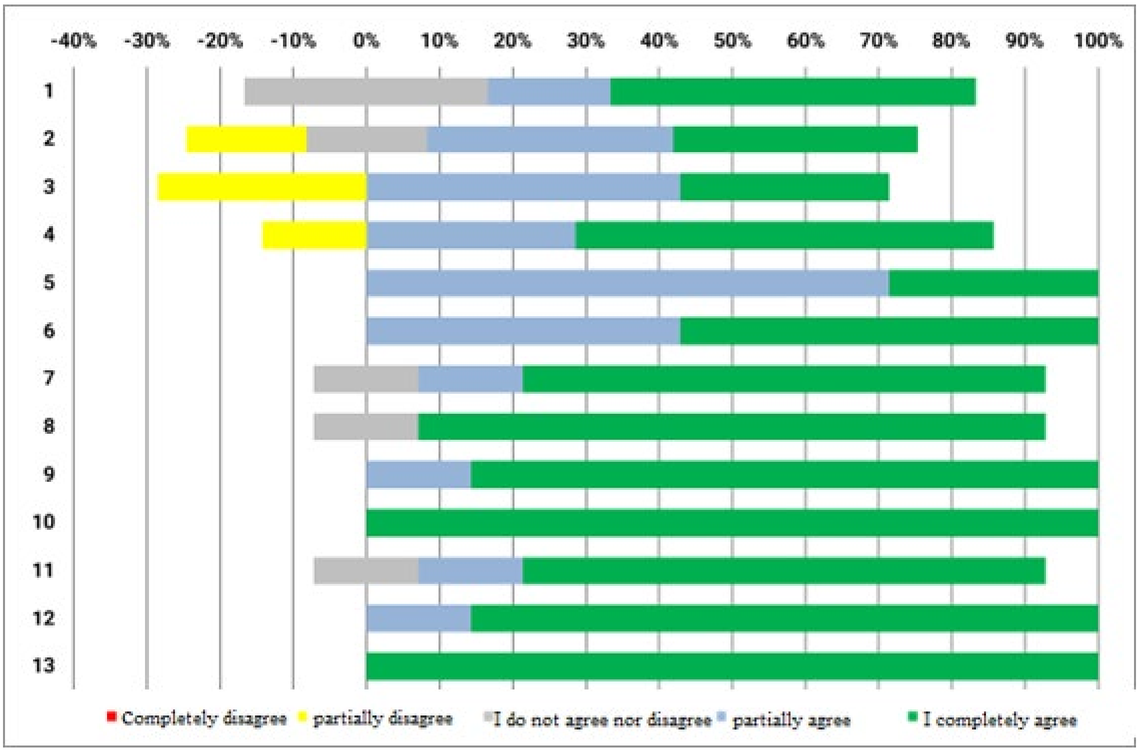


Figure 12: *Graph of the Likert Method Result – Group 3 – IEN Radiological Protection*



- Evaluation of the graph in Figure 10 - Group 1 – Nuclear Area Technicians:

1. Compliance of the model with current legislation (questions 1, 2 and 3):

   From the graphs it can be concluded that the interviewees agreed with the model's compliance with the legislation, and had a higher prevalence of positive responses than the other groups. It is important to reinforce that the group in question works in radiopharmacy, and evaluate compliance with the current standards both in structure and in terms of the responsibilities of pharmacists that are in accordance with Resolution No. 486 of September 23, 2013 of the CFF, which has applicability to the experience of the respondents. (CFF, 2013)

2. Methodology that will be applied in training (questions 4, 5 and 7):

   From the graph it can be concluded that the respondents agreed with the proposed methodology for training in a virtual environment.

3. Feasibility of the virtual model for simulation and training (questions 6, 8, 9, 10, 11, 12 and 13):

From the graph it can be concluded that the respondents agreed with the viability of the virtual model, but had a lower prevalence of positive responses in relation to the other groups. It is important to emphasize that this group does not focus on the area of technology, however, they are These are the professionals who can be trained, in the way recommended here, through the new tool, which gives the opinion of this group a particularly important relevance.

- Evaluation of the graph in Figure 11 - Group 2 – IEN Human / System Interface:

1. Compliance of the model with current legislation (questions 1, 2 and 3):

From the graph it can be concluded that the respondents agreed with the model's adherence to legislation, but not so favorably, and it is important to clarify that the professionals in this group are not from the area of radiopharmacy and have little or no knowledge of current standards. for this service, and even for this reason, some of the interviewees did not even answer the questions from this group.

2. Methodology that will be applied in training (questions 4, 5 and 7):

From the graph it can be concluded that the respondents agreed with the proposed methodology for training in a virtual environment, and had a higher prevalence of positive responses than the other groups.

3. Feasibility of the virtual model for simulation and training (questions 6, 8, 9, 10, 11, 12 and 13):

From the graph it can be concluded that the respondents agreed with the viability of the virtual model, and had a higher prevalence of positive responses than the other groups.

In conclusion to categories 2 and 3 of the group evaluated here, it is important to emphasize that the group focuses on technology and is familiar with methodologies such as this, which makes this group's opinion even more relevant.

- Evaluation of the graph in Figure 12 - Group 3 – IEN Radiological Protection:

1. Compliance of the model with current legislation (questions 1, 2 and 3):
   From the graph it can be concluded that the respondents agreed with the model's adherence to legislation, but not so favorably, with this group being the least adherent to this category. It is important to clarify that after analyzing the comments and suggestions of this group (Appendix B), it was identified in the evaluators' comments, a greater incidence in the area of safety and radiological protection, which in turn is the focus of the group, which gives even more relevance to this group's opinion for improving the model in terms of radiological protection, where we can base ourselves on CNEN 3.05.

2. Methodology that will be applied in training (questions 4, 5 and 7):
   From the graph it can be concluded that the respondents agreed with the proposed methodology for training in a virtual environment.

3. Feasibility of the virtual model for simulation and training (questions 6, 8, 9, 10, 11, 12 and 13):

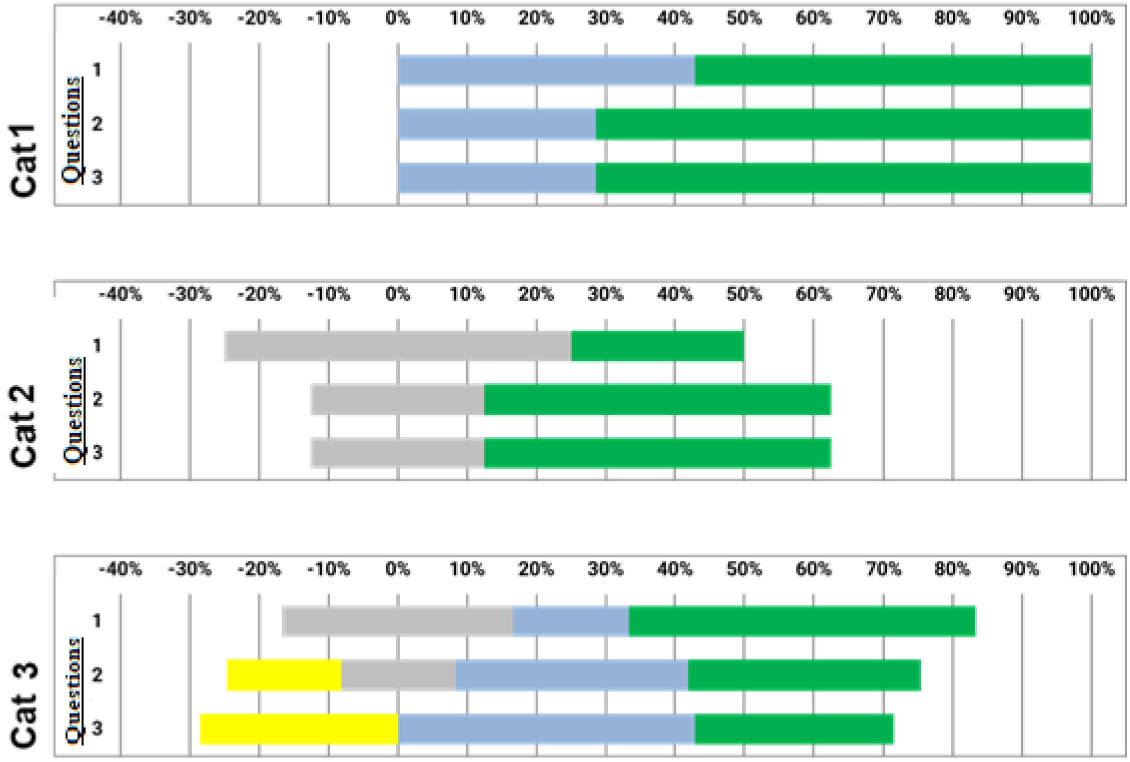
   From the graph it can be concluded that the respondents agreed with the viability of the virtual model, and even though they were not a group focused on this type of technology, they understood the proposed model as viable.

5.1.1. COMPARATIVE EVALUATION OF THE FIRST GROUP OF QUESTIONS

Adherence of the model to current legislation:

As can be seen in the graph of the 1st Category (Cat 1) of Professionals (Nuclear Area Technicians), the respondents agreed with the adherence of the model to the legislation and had the highest prevalence of positive answers (FIGURE 13).

Figure 13: *Comparative Analysis of the Likert Method Result – First Group of Questions*

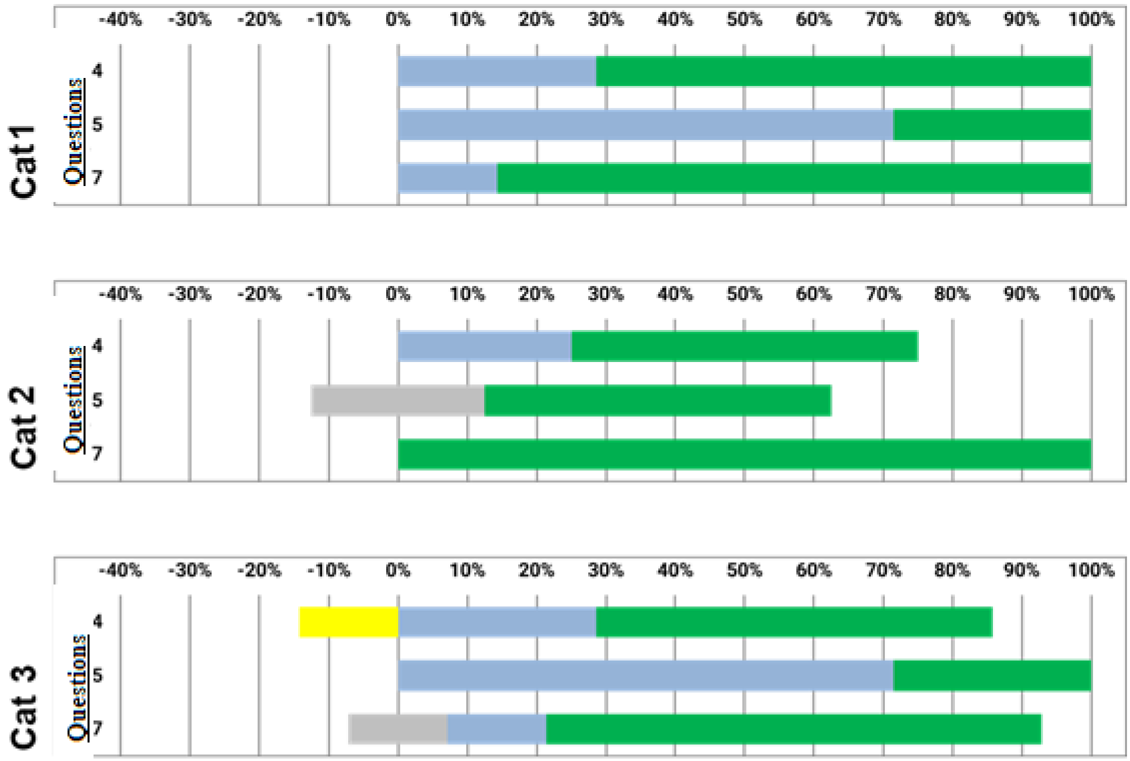


5.1.2. COMPARATIVE EVALUATION OF THE SECOND GROUP OF QUESTIONS

Methodology to be applied in Training.

As can be seen in the graph of the 2nd Category (Cat 2) of Professionals (Human Interface / IEN System) the respondents agreed with the methodology and had the highest prevalence of positive answers (FIGURE 14).

Figure 14: *Comparative Analysis of the Likert Method Result – Second Group of Questions*

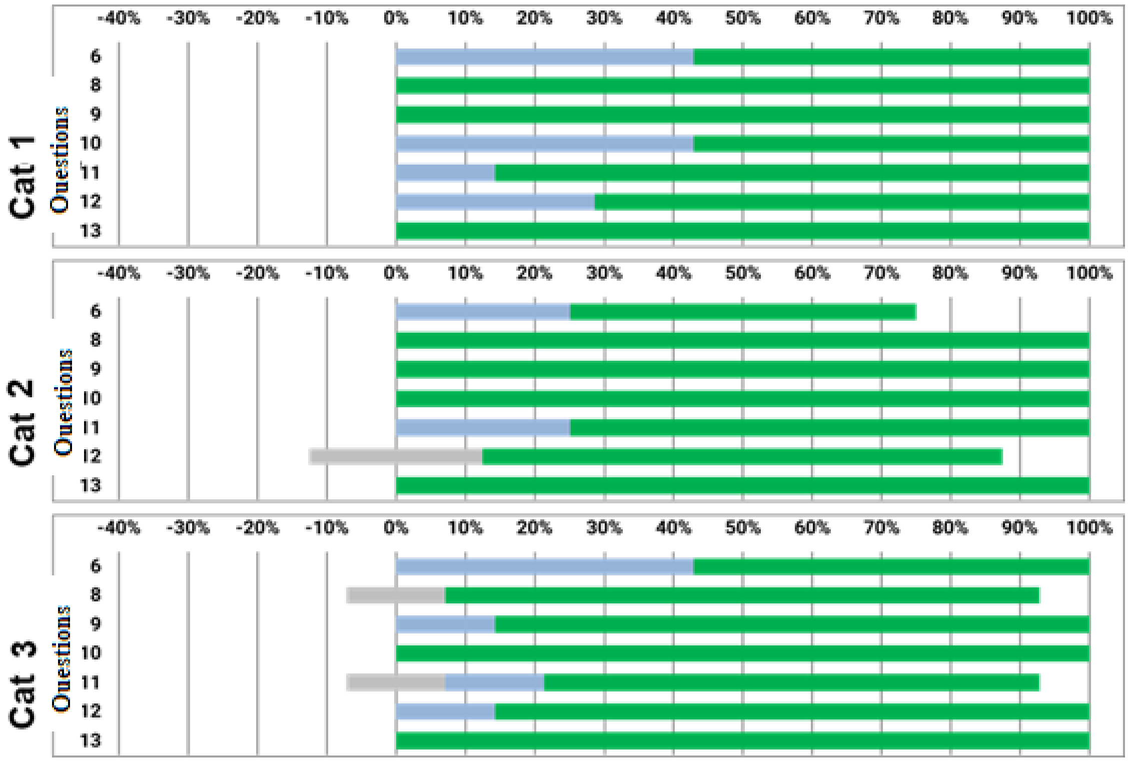


5.1.3. COMPARATIVE EVALUATION OF THE THIRD GROUP OF QUESTIONS

Viability of the virtual model for simulations and training.

As can be seen in the graph of the 2nd Category of Professionals (Human Interface / IEN System) the respondents agreed with the viability of the model and had the highest prevalence of positive answers (FIGURE 15).

Figure 15: *Comparative Analysis of the Likert Method Result – Third Group of Questions*



6. CONCLUSION

In view of the arguments presented, the study showed that VR has much to add to the training of different professionals in the field of nuclear medicine and technical applications for radiopharmacies. To evaluate the tool developed in this work, a questionnaire was applied to several professionals who were separated into groups, according to their professional activity, as previously described. Thus, it was possible to obtain information that could be used in new works.

According to the analysis of the results, it was evidenced that the applied methodology and the response of the professionals of the nuclear segment, referring to the presentation of the virtual environment (simulator), proved to be viable, for the proposal of this dissertation.

Based on the results presented, this article achieved its purpose with the use of virtual reality, through simulators, allowing the creation of a graphical environment with a realistic appearance, in which the user can navigate in this environment, feel and manipulate the virtual world. It is worth mentioning that the environment evaluated here sought to follow all current rules and legislation, allowing the immersion in the virtual environment to be as close as possible to the real environment. Therefore, it is expected that the training carried out through VR will be an efficient complementary method, since the training can be carried out countless times and the learning can be designed in stages, facilitating the absorption of content by the users, until the necessary skills are acquired, and information assimilated correctly.

It is understood that the developed application serves as subsidies for techniques in the training of professionals who work in radiopharmacy. This demonstrated that, in addition to being viable, it reduces financial resources and increases the safety and radiological protection of hospital radiopharmacy professionals.

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