Curricular configurations of the contemporaneous academic training of medical physicists in Rio Grande do Sul- Brazil

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Abstract
Education in medical physics is a contemporary theme of research that has gained worldwide popularity. In Brazil there are still few studies about this subject. The objective of this work is to present and discuss elements that structure the Curriculum Pedagogical Projects (CPPs) of undergraduate programs in medical physics offered in the State of Rio Grande do Sul, Brazil. From the analysis of national and international materials, an outline was made of the four programs established in the State. In summary, the four CPPs are based in an active methodological approach, all being classified as innovative CPPs. Each program justification and graduate profiles are based on the local, cultural and social realities. General objectives, specific objectives and areas of activity are guided by the institution philosophy in which the undergraduate program is inserted. The curricula of each undergraduate course agree with each institution's guidelines and particular characteristics. The results of this work may contribute to the construction of an increasingly multidisciplinary and interdisciplinary program that is aimed to prepare a professional that is able to work according to the reality of Brazil.

Keywords: Training. Medical Physics. Curricula and evaluation.

Resumen
La educación en física médica es un tema contemporáneo de investigación que ha ganado popularidad en todo el mundo. En Brasil aún existen pocos estudios sobre este tema. El objetivo de este trabajo es presentar y discutir elementos que estructuran los Proyectos Pedagógicos Curriculares (CPP) de los programas de pregrado en física médica que se ofrecen en el Estado de Rio Grande do Sul, Brasil. A partir del análisis de materiales nacionales e internacionales, se hizo un esbozo de los cuatro programas establecidos en el Estado. En resumen, los cuatro CPP se basan en un enfoque metodológico activo, todos clasificados como CPP innovadores. La justificación de cada programa y los perfiles de los egresados se basan en las realidades locales, culturales y sociales. Los objetivos generales, los objetivos específicos y las áreas de actividad están guiados por la filosofía de la institución en la que se inserta el programa de pregrado. Los planes de estudio de cada carrera de grado concuerdan con los lineamientos y características particulares de cada institución. Los resultados de este trabajo pueden contribuir a la construcción de un programa cada vez más multidisciplinario e interdisciplinario que tiene como objetivo preparar un profesional que sea capaz de trabajar de acuerdo con la realidad de Brasil.

Palabras clave: Formación. Física Médica. Currículum y evaluación.

I. INTRODUCTION

Medical physics emerged in the 20th century with the advent of ionizing radiation for diagnosis and treatment. The first medical physicists were mostly researchers who purposely or accidentally applied their experiments to hospital practices. The discovery of X-rays by Wilhelm Conrad Röntgen and the studies of Leonardo da Vinci employing innumerable physical and mathematical concepts to observe and study the human being [1] are considered historical marks of medical physics. The basic concept of medical physics is the application of physical principles to the practice of medicine. According to [2], the field of activity of the professional is centered on academic research, radiation protection, radio-diagnosis, nuclear medicine, and radiotherapy. The medical physicist can also work in business sectors that employ ionizing and non-ionizing radiation, such as nuclear power plants, cyclotrons, and companies that provide services to hospitals.

Over the years, worldwide concern about the level of qualification required for professionals in this area has increased [3]. This discussion arises along with the major changes contemporary society is undergoing, in which truths become provisional and values are constantly being questioned. An ever-increasing amount of information and continuous cooperation amongst different medical fields require a relationship of mutual exchange between professionals [4]. The work of the medical physicist is particularly inserted in this context, as it is an interdisciplinary and innovative profession dealing with technologies and methods in constant evolution [5].

The relevance of the topic under study culminated in the creation of documents and recommendations from international organizations: Report No. 197 of the AAPM (American Association of Physicists in Medicine) [6], which contains curricular suggestions for undergraduate degrees in medical physics, and the document containing suggestions for academic training and certification in Latin America authored by the International Atomic Energy Agency (IAEA) in 2010 [3, 6, 7, 8].

In Brazil, medical physics arose in 1956. However, the formal structuring of the area only began in 1969 with the establishment of the Brazilian Association of Medical Physics (ABFM, from the Portuguese Associação Brasileira de Física Médica). That association implements the certification process in the areas of radiotherapy, nuclear medicine and radio diagnosis.

The certification process comprises an exam and grants the title of specialist [8]. Moreover, the Radiation Protection Supervisor examination (for each one of the professional areas) of the National Nuclear Energy Commission (CNEN, from the Portuguese Comissão Nacional de Energia Nuclear) aims to qualify the professionals working in the various areas of Medical Physics. Contrary to most countries where the medical physicist profession is already regulated and well established, in Brazil the profession was only regulated in 2018 under Law No. 13691 of July 10, 2018 [9]. According to the work of [8], the first medical physics course was created in 1990, in Porto Alegre, capital of Rio Grande do Sul state, and since then, about ten new undergraduate courses have been created in Brazil.

However, there are few graduates to cover the lack of professionals in the country, and there is an uneven distribution of medical physicists and financial resources [5]. According to a consultation held in May 2018, through the ABFM website, there are 715 medical physicists currently employed in Brazil, those being active members. It should be noted that the exact number of non-members is not documented [10].

The study on the teaching of the profession of medical physicist in Brazil is in its infancy, thus there are few national reports on this subject. The present work is based on the study of [8], which presents a data survey on undergraduate, postgraduate, and residency programs in medical physics in Brazil until 2012. Another study, namely “Panorama of the of Medical Physics Programs in Brazil”, presented in the Brazilian Congress of Medical Physics (CBFM, from the Portuguese Congresso Brasileiro de Física Médica) in 2016, provides a numerical approach on the structure of medical physics programs in Brazil, analyzing items such as course duration, number of annual openings, average number of freshmen and graduates, hour workload per area of knowledge, and the administrative category of the higher education institutions offering the programs (IES, from the Portuguese Instituições de Ensino Superior) [11].

The absence of materials detailing the subject motivate the present study. Based on the international recommendations and the knowledge of the current panorama of evolution in the number of medical physics programs in the country, it becomes fundamental to analyze the structure of medical physics and physics with application in medicine programs, analyzing in detail curricula, designs, and methodologies, as well as the profile of graduates as a way of identifying the main challenges and gaps in the training of the medical physicist, which is the purpose of this study. Thus, this article aims to present and discuss the elements described above, presenting an overview of medical physics programs in Rio Grande do Sul State.

II. THEORETICAL CONTRIBUTIONS OF THE STUDY

The definition of curriculum is based on the fact that it covers all important aspects of a teaching program. Four branches that define the curriculum can be mentioned: the stated curriculum, present in the documents of the institutions; the taught curriculum, which is the interpretation of what is stated by educators and the consequent application in class; the hidden curriculum, which is all that has resulted in learning for the students; and finally, the learned curriculum, the sum of the learning synthesized by the students [12]. This research was based only on the concept of the "stated" curriculum, taking as reference the content of official documents of the educational institutions participating in the study. According to the authors, it should be clear in the stated curriculum: the purpose of the program, the expected results, the student learning assessment components, the learning targets throughout the program, and the structure of the teaching environment and its methods.

Throughout history, curriculum has been understood and conceived in the light of traditional, critical and post-critical theories, through its different visions regarding the construction of the teaching-learning process. The first and oldest theory, in which the teacher is at the center of the teaching-learning process, addresses an efficient organization for specific goals to be achieved. The contents are behaviors that must be achieved, and teaching is something technical [13, 14]. According to the author, in contrast to technicism, critical theories arose, and with them a social construction, based on the community as a whole, questioning the curriculum regarding social, political and economic structures. According to the same author, the core of this thinking is structuralism. The latter theory, called post-criticism, on the other hand, places importance on identities and differences. Here the mutable truths stand out and the construction of the knowledge is given by the listening of the actors, by cultural diversity and the experiences of each individual.

As those theories were questioned, teaching-learning methodologies were also modified over time. According to [15], epistemologically, in a first context what ruled was the image of the teacher as the holder of all knowledge and the student was considered, nothing more nothing less, than a blank notebook. The next step was the emergence of the so-called active methodologies, where the focus of the teaching process becomes the protagonism of the student, as well as the mutual exchange of knowledge between teacher and student. In this context, teaching-learning occurs through questioning, analysis, studies and research aimed at problem-solving [16]. Teaching encompasses all aspects of the individual, both emotional and prior knowledge [17], creating ethical, social, critical, autonomous, and questioning behavior [18]. Here the proposals of interconnection between theory and practice arise and interdisciplinarity plays the central role as a process of integral teaching, providing the application of the concepts learned in favor of society.

Starting from a context in which the student is treated as a tabula rasa and knowledge follows a banking model, *i.e*. must be memorized and reproduced [19], questions begin to arise. The teaching-learning process shows itself as the submerged part of an immense iceberg: it has a dynamic, non-linear character [20], with numerous actors and means to be constructed. In this context Active Methodologies are born, which, according to [16] "(...) are based on ways to develop the learning process, using real or simulated experiences, aiming at the conditions to successfully solve challenges arising from activities essential to social practice, in different concepts". In those methodologies, knowledge is suggested and explored by both the teacher and the student, creating acritical, questioning and participatory profile [18], in search of constant knowledge renewal.

In order to build a plural knowledge, a number of methodologies have been put into practice, which are addressed in the works of [4] and [16], and analyzed in the present study within the Curricular Pedagogical Projects (PPCs, from the Portuguese Projetos Pedagógicos Curriculares). Examples of active learning methodologies are the Problem Based Learning (PBL), consisting on the resolution of proposed problems, stimulating an active and autonomous attitude from the student , the Methodology of the Arch of Problematization of Manguerez, which associates the keywords of learn doing, widely used in the health sciences, and brings the constant theory-practice relationship. This method must contemplate the principles of learning to know, learning to do, learning to live with, and learning to be [21], the stimulation and development of critical and creative thinking. Another teaching-learning method also used in the health sciences is the one based on Competences, addressed in the work of [12], consisted of reachable and specific learning objectives and a clear assessment method.

According to [17], learning in adult education is driven by problematization, through problem-solving and overcoming challenges, relying on a previous experience of those involved. Educational institutions and educational documents, especially those dealing with health sciences education, started to rethink the design of curricula in the early 2000s [22]. In accordance with problematization and contribution to the society, as stated by the Law of Directives and Bases of National Education [23], the National Curricular Guidelines (DNCs, from the Portuguese Diretrizes Nacionais Curriculares) for the Courses of Physics [24] (pages 3-4) propose the challenge of "broad and flexible training that develops skills and necessary knowledge for current expectations and ability to adapt to different perspectives for future action." Those DNCs delimit a common core of training for all physics programs, with a workload equal to half the total program workload, constituted of topics of general physics, classical physics, modern and contemporary physics, mathematics, and complementary courses. The lack of specific guidelines for medical physics courses corroborates the absence of a solid definition with respect to the profession, which may a priori allow the emergence of varied curricula lacking a standard training. For the country to have professionals with appropriate qualification, it is necessary to strengthen the training bases, counting on undergraduate programs with a strong foundation in physics and an adequate application of this knowledge in the different medical areas. According to [22] (page 1192) there is a need for "revisions that make possible a greater specification of the organization of knowledge and practices in an interdisciplinary and inter-professional way." Integrated academic research is also an essential component of the curriculum, as the impact of the outcomes affects clinical practice more than all current medicine efforts [1].

III. METHODOLOGY

The study has an exploratory nature, for it is a novel practice when considering medical physics as an academic subject, generating new information and summarizing relevant knowledge within the areas of action of Medical Physics.

Moreover, it can be defined as strategic research, since the results can be used for various purposes, such as for community information, professionals and students, in order to help in a future consolidation of medical physics curricula, focusing on the training of medical physicists. Differently from previous works in the area, this work is a qualitative-quantitative study, seeking to obtain quantitative data regarding the pedagogical project of each undergraduate program and yet making a qualitative analysis of the processes and structure of medical physics within the various educational institutions in Rio Grande do Sul State.

Firstly, a document search was performed about the national and international panorama of teaching medical physics, to obtain information that contemplates recommendations, challenges, and even that addresses the recognition of the profession and its impacts on graduation rates. Publications of the world's leading agencies on medical physics, such as the IAEA and the AAPM, which deal specifically with the construction of professional knowledge and how the programs in the area should be structured, were considered. At the national level, the analysis was made in the light of numerous documents, such as the DNCs for bachelor's and Teaching degrees in Physics, and the work of [22]. Statistical data from the ABFM was also used.

Data was collected on the PPCs for the Medical Physics or Physics with emphasis in Medical Physics programs in Brazil, starting with the analysis of the PPCs of programs offered in Rio Grande do Sul , where the oldest medical Physics undergraduate program is located. The state has four Medical Physics programs, three of which are offered by private institutions and one by a federal university. For confidentiality purposes, each institution will be referred to by a letter code. The following table summarizes the basic information for each course:

TABLE I. Contains, respectively, the letter by which the program will be mentioned throughout the study, the date of creation and the type of program (Medical Physics, as FM, or Physics with an emphasis on Medical Physics, with the acronym FEFM).

Course	*Date of creation*	*Type*
A	1990	FEFM
B	2014	FM
C	2001	FM
D	2018	FM

The study was divided in four stages: data collection, pre-analysis, analysis of results, and interpretation. Refined data for analysis, arranged in table 2, were separated into two axes: the curricular axis and the professional profile axis.

The analysis and interpretation of the qualitative data was inspired by [22] and based on [25], with the elaboration of two main thematic categories, divided into sub-themes, from the data collected in the PPCs of medical physics programs, as described in table 2.

The quantitative analysis of data regarding curricular matrices and workload distribution was performed using the Microsoft (R) Office Excel software.

TABLE II. Data obtained from PPCs and organization of the themes and sub-themes under analysis. The number that precedes each item in the table corresponds to the theme (full number: 1 and 2) and to the sub-theme (1.1,1.2, etc.) that will be discussed throughout the work.

1. Curricular Axis	*2. Professional Axis*
1.1. Total Workload	2.1. Egress Profile
1.1. Number of openings offered per year	2.2. Areas of expertise
1.1. Curricular length (in semesters)	2.3. Curricular matrix
1.2. Justification	2.4. Workload per program
1.3. Teaching/learning methodologies	-
1.4. General goals	-
1.5. Specific goals	-

IV. RESULTS AND DISCUSSION

The results of this study are presented in thematic categories according to the performed analysis, following the classification presented in Table 2. Data referring to each theme and sub-theme resulting from the analysis of the documents of the courses participating in the study is presented and discussed below.

A. theme 1. curricular axis

- *Sub-theme 1.1. Total workload, number of openings offered per year and curricular rates (number of semesters planned for each program).*

From the data of the PPCs of the courses, shown in Table 3, the initial panorama of each program could be traced.

TABLE III. Information corresponding to the total workload, number of openings offered annually and curricular rates. This information is contained in the PPC for each program.

Course	*Total Workload*	*Number of vacancies (annual)*	*Curricular payment (semesters)*
A	2940	60	8
B	3420	40	9
C	3145	40	9
D	2700	50	8

According to the Resolution No. 2 of 18 June 2007 [26], the minimum workload required for physics programs is 2400 hours, with a duration of at least three or four years, corresponding to six or eight semesters, respectively. Openings vary according to the infrastructure and policies of each institution. Course B has the highest workload, and course C has the lowest workload. The density of hours distributed throughout the semesters is analyzed in Sub-theme 2.2 of this study.

- *Sub-theme 1.2. Justification*

Justifications for each program address the reasons for the creation of the program, according to local, cultural, and social reasons. In short, PPCs are based on the demand for competent professionals, who can occupy positions in hospitals, clinics, industries, among other centers and services that use ionizing and non-ionizing radiation. The analysis of this item for each PPC is shown below.

PPC A: the PPC of institution A addresses the information about the curricular adaptation of Medical Physics and Geophysics programs, both derived from the bachelor's in physics program. In this PPC, a specific justification for medical physics is not explicitly stated.

PPC B: offered by a federal public university, course B remarks the creation of a new training center, increasing the number of openings for the training of medical physicists in the region, promoting the development of new technologies and the expansion of the institution.

PPC C: the institution is located in a city that is reference in health and education in the State's countryside and considers the regional and national needs of professionals to participate in health and related processes. The creation of the course is reasoned by the multidisciplinary character and the extent of its professional actions, ranging from teaching to acting in health institutions.

PPC D: addresses the need for improvement of the regional industrial and research sector, focusing on electronic devices, electrotherapeutic, and irradiation sectors. The program shows a complementary character with the Biomedical Engineering program, creating a multidisciplinary context with opportunities for technological development.

- *Sub-theme 1.3. Teaching-learning methodologies*

Teaching-learning methodologies were analyzed through a keywords search in the literature. The investigation considered only what is stated in the documents, and therefore, it emphasized that the reality of the different programs can be different as the process depends on its actors: teachers and students, who are individuals with diverse backgrounds. As in the work of [22], PPCs were considered innovative once they contemplate the use of active methodologies, encouraging interdisciplinarity, and creating a critical, ethical, and humanistic profile.

PPC A: teaching methodologies are based on the four pillars of learning to learn, learning to do, learning to live together, and learning to be, affirming that learning to learn is extremely relevant nowadays due to the rapid changes and innovations, the new knowledge required, and to the dynamism of the world. The aim of the program is to provide the students with comprehensive and flexible training, enabling them to obtain relevant skills and abilities to the profession. In this panorama, the development of the autonomy to learn and to question is fomented, with the student as the owner of their own learning process. This profile is built together with the exchange of information and knowledge between teachers and students, considering the emotional aspects of the experiences, according to [18] and [27], who reported that learning is about the development of the individual in terms of knowledge, emotional skills, attitudes, and values.

PPC B: the course aims at a critical education profile, with a student who is capable of learning to learn, who works harmoniously with other professionals and teams, who is aware of the social reality, and who works consciously to improve society [18]. This student is the protagonist of the learning process. Tchers measured the learning process and were suggested to use active methodologies in classes and several teaching-learning strategies. As in PPC A, there is an exchange between teacher and student. The course values the development of a student with professional and intellectual autonomy, concerned with cultural issues, who knows how to discuss and debate, work in groups, and has a theoretical and practical background.

PPC C: teaching practices are focused on solving problems and exercises, with intense contact between theory and practice through different means, teaching methods, and mediation by the teacher. Interdisciplinarity is present in teaching, outreach, and research projects. The methodology of teaching through problematization is guided by the student becoming an agent of social transformation while solving and questioning real problems [4].

PPC D: uses the competence approach through problem-solving and decision making. In this model, the competencies that are expected to be achieved must be in the form of specific objectives [12]. Students are encouraged to work on aspects such as questioning and investigative profile, teamwork, caring and humanization, and mastering interdisciplinary knowledge. The course also encourages interactions in the development of the teaching-learning process. The student is active throughout their education, being autonomous, reflective, and ethical.

All PPCs deals directly or indirectly with active teaching-learning practices, with the student being the protagonist of their learning, and constantly looking for professional betterment. Furthermore, interdisciplinarity and choosing freely the complementary courses make the learning process more thorough. Each curricular matrix 's very particular. However, all PPCs are based on active learning methodologies and situations that are close to real life, which better prepares the future medical physicist, allowing the development of their professional activities. In conclusion, all PPCs analyzed can be classified as innovative PPCs.

For a more detailed understanding of the application of these methodological proposals we suggest an analysis of the everyday situation in the institutions, observing whether the PPCs are followed, and which teaching, and assessment strategies are employed.

- *Sub-theme 1.4. General and Specific Objectives*

In order to answer to that question, we look into the DNCs of the Physics Programs, namely the essential, general, and specific skills established in the document. According to them, in face of numerous possible actions, a set of common basic qualifications is necessary, those being clear objectives of formation.

General skills must be acquired independently of the training bias, which are:

To use mathematics as a language for the expression of natural phenomena; to solve experimental problems, from recognition of measurements to the analysis of results; propose, elaborate, and use physical models, recognizing their applicability domains; concentrate efforts and persist in finding solutions to elaborate problems; to use scientific language in the expression of physical concepts, in the description of scientific work procedures and in the dissemination of its results; to use the various computer science resources, knowing the basics of programming languages; to know new techniques, methods, and instruments use, either in measurements or in data analysis (theoretical or experimental); to recognize the relations between Physics and other areas of science, technologies and social instances, especially contemporary ones; present scientific results in different forms of expression, such as reports, papers for publication, seminars and lectures [24] (page 4).

Specific skills are not emphasized by the guidelines, as they depend on the training focus of each program.

The General Objectives of the four PPCs account for an extensive focus in physics so that the medical physicist can apply their knowledge in different professional areas. PPCs B, C and D focus on the health sciences area, unlike the PPC A which is more general, as the objectives described in that PPC correspond to other physics programs offered by the institution. The ethical and conscious use of knowledge for the benefit of society is addressed in all documents, as "Social responsibility today is a requirement of the whole society towards its professionals, as well as ethical behavior" [18]. All programs briefly address the skills predicted by DNCs, applying them to the area of medical physics and detailing them further in the description of specific objectives and/or competencies.

The specific objectives are clearly stated in PPCs B and C, while in the PPCs of programs A and D the information is described in the skills and abilities section. The four programs emphasize the idea of a professional with an ethical profile, conscious, and committed to society, agreeing with [18]. As well as the DNCs for Physics programs, the specific objectives of PPCs A, B and D explicitly state that the professional must master the fundamentals of physics and be able to apply such knowledge into their activities. Because medical physics is a profession in direct contact with technology and produces novel information, PPCs address the professional's ability to handle and use technology in order to improve processes and to work in a group, and with other areas. Finally, the interest to learn and improve must be constant, since the scientific area is always in constant evolution. PPC C also places the general skills in the section entitled "Skills and Abilities."

B. Theme 2. axis of the professional profile

Through the National Education Guidelines and Bases Law [23], institutions are encouraged to link pedagogical practices to social reality, fostering new knowledge and establishing a professional profile that uses the learned contents, and applies them to solve national and international problems. According to [4], the professional is defined as a subject that holds ethical, technical and political skills, capable of acting in a diversity of situations.

- *Sub-theme 2.1. Graduate's profile*

The curriculum, besides the description of all the activities and their structure, should explicit the expected results from the graduates [12]. The graduate's profile corroborates the social context in which the program is inserted, being flexible to regional aspects, yet in accordance to the general and specific objectives of the corresponding PPC.

According to IAEA, in the document entitled The medical physicist: Criteria and recommendations for their academic formation, clinical training and certification in Latin America, the graduate profile of an undergraduate program will consist of a professional with skills in administering and advising on medical technology, technological development of equipment as well as diagnosis and treatment, participation in therapy and treatment planning with radiation use, implementing protection measures and optimization, be participative in the process of imaging and act in the development of software (page 20) [7]. Below are displayed the definitions of graduate profiles for each program:

PPC A: PPC A discusses the profile of a professional that connects the theoretical and/or experimental instruments of formal physics to the health sciences, who knows how to work in teams and to communicate with different professionals of related areas, enforcing the guidelines. The document emphasizes this profile, presenting a series of competencies that are related to the predicted by the IAEA material , such as being involved in research; managing, organizing and acting in a harmonious way with teams; actively participating in quality control, optimization and acquisition, in processing and analysis of analog/digital images and digital signals, as well as in the consulting process; planning and commissioning installation of new diagnostic and treatment equipment, mastering the correct use of radioactive sources, and following the routines of their corresponding services.

PPC B: describes a professional with a broad and interdisciplinary profile who, as stated in PPC A, connects the dense knowledge in physics with the health sciences, acting in a harmonious way with multidisciplinary teams. The professional should be able to approach new and traditional problems, acquiring and updating technical and scientific knowledge, thus acting in a critical, cooperative and dynamic way. This PPC does not present a competence and skills section directly related to the profile mentioned by the International Agency but agrees with the DNCs.

PPC C: presents the graduate profile in the same fashion as the PPC of program B, adding to it the ability to adapt to the demands and advances of scientific and technological fields, to conjectural requirements and to the changes of the areas, always reevaluating their performance. In the competences section, The PPC includes participation in research, the use of computational tools and dedication to the education and training of individuals.

PPC D: profiles the graduate as a critical, ethical and conscientious professional with multi and interdisciplinary training, who is able to use their knowledge for scientific and technological development, applying the results in the area of health sciences. As in the previous PPCs, it mentions the capacity of acting in multidisciplinary teams, in favor of society. Moreover, the PPC highlights an entrepreneurial profile, encompassing design and computational thinking skills. In this document, as well as in the PPC of program A, the graduate skills are explicit, including abilities to supervise, follow and guide medical services, participating in equipment quality control, acquisition, maintenance and training of teams; to work in image processing and optimization, medical laser application, optical techniques, spectroscopy and radiation applications in the three large areas; to know how to interpret data, texts and information taking a critical approach and always seeking new solutions; to be autonomous in searching for constant improvement and actively participating in scientific research. Like program A, this PPC agrees with both the Guidelines and with the IAEA.

PPCs B and C present a more generic profile compared to PPCs A and D, and the use of knowledge in the health sciences is reported. However, those PPCs do not explicitly describe how and whether the acquired knowledge would be unequivocally used in medical physics. For PPCs B and C, there is agreement with the IAEA document regarding the use of scientific and technological knowledge in the health sciences, but there is no correlation with the IAEA.

- *Sub-theme 2.2. Areas of expertise*

The areas of activity are defined based on each undergraduate program, considering the specific area in which the graduate will work as a medical physicist. The guidelines for the activities stated in the documents are directly related to the graduate's profile, and consider the particularities of each program, regional and local aspects. Knowledge construction takes place in order to apply this knowledge in the work environment, and for this it is necessary to achieve a series of objectives or competencies that will characterize the graduate's profile program. That process should be thoroughly described in the document as this information will support the curricular matrix of each program.

PPC A: mentions areas of activity such as sanitary surveillance organizations, health institutions, medical equipment companies, electronics, measurement, and information technology.

PPC B: main areas of activity are nuclear medicine, radio-diagnosis, and radiotherapy. The graduate should be able to act as researcher and teacher, participate in companies developing and marketing health-related equipment, service providers, health surveillance, controlling and regulating organizations for the use of ionizing radiation and in the imaging and therapy equipment industry.

PPC C: program C addresses the possibility of acting in the areas of research or teaching, promoting optimization and creation of new technologies and the dissemination of knowledge; activities in hospitals, clinics, and industry.

PPC D: cites the areas of research and development, generation and analysis of images, biomedical instrumentation, participation in process development in organizations or products, and public companies.

The compulsory parts of the curricular matrices of each program agree with the vision of the Institutions of Higher Education (IES) on the areas of activity to which the students are directed, encouraging the formation of an active professional identity.

PPC A: Compulsory training can be performed at health institutions such as clinics, hospitals, medical physics companies, medical physics research groups, and regulatory agencies in the area of medical physics.

PPC B: internship can be performed within the three major areas of Medical Physics: radio-diagnosis, nuclear medicine and radiotherapy.

PPC C: areas of radio-diagnosis, nuclear medicine, radiotherapy, nanomaterials, among others are suggested. The internship can be done in clinics, service providers, health activities, hospitals, and in public and private institutions.

PPC D: activities may be carried out in research and development, biomedical instrumentation, generation and analysis of medical images, and in agencies acting in the development of products and/or processes in medical physics, either public or private.

- *Sub-theme 2.3. Curricular matrices and workload by course*

Curricular matrices and hourly loads are used to analyze and compare curricula of different programs, obtaining a more detailed evaluation of the profile of the student. Through the analysis of the offered courses, areas of knowledge, and the workload, it is possible to design a graduation program and examine the alignment with the aforementioned areas of practice.

The DNCs for Physics programs predict training through a common core (with about 50% (fifty percent) of the workload) for all physics programs, and a specialized nucleus. Being constructed on the basis of specialized sequential modules, medical physics falls into the category of interdisciplinary physics.

The common core, according to DNCs, consists of mathematics, general physics, classical physics, modern physics, and other science courses. The following are the courses related to each of those areas:

a) Mathematics: differential and integral calculus, analytical geometry, linear algebra, differential equations, concepts of probability and statistics and computation;

b) General Physics: mechanics, thermodynamics, electromagnetism, properties of waves, and application of theory in the laboratory;

c) Classical Physics: courses whose concepts were established around the twentieth century, contemplating disciplines such as classical mechanics, electromagnetism, and thermodynamics;

d) Modern and Contemporary Physics: quantum mechanics, statistical physics, relativity. Practical application in the laboratory is strongly encouraged by the DNCs.

e) Complementary Disciplines: they broaden the education of the student, addressing subjects such as chemistry, biology, and human sciences (ethics, philosophy, history of science, etc.).

The sequential module for medical physics will then consist of the disciplines that build the emphasis of the course.

Curricular matrices and syllabi of each program were analyzed for those programs presenting high dissimilarities, considering as basis the courses provided by the DNCs. Courses which are unique in each PPC, those agreeing with the profile of the IAEA graduate, or those which are addressed in a specific program and/or that are divided in more courses (an example is the dismembration of basic physics courses into specific courses by area) were studied. In human sciences, the Libras (Brazilian Sign Language) course is required by [28], as well as the courses foresaw by the DNCs, thus they were taken into account.

PPC A: The program is organized as: General and Experimental Physics, Mathematics, Integrative Training, Complementary Disciplines, Philosophical and Humanistic Culture, Research Training, Professional Training, Advanced Theoretical and Experimental Physics, Pedagogical Training and Training in Medical Physics.

a) Exact Sciences: The experimental classes in the axis of physics are taught in an integrated way with the theory, supported by an advanced axis. The axis of Integrative Training includes astronomy, instrumentation, and Origins and Development of Physics, while the axis of Complementary Disciplines includes general chemistry and computation. Unlike the other three PPCs, there is a relativity course.

b) Specific Area: a course in digital image processing is offered. The three major areas are divided into corresponding courses. Radiation Physics is divided into the segment of ionizing, non-ionizing, and ultrasonic radiation. Another point to highlight is the presence of an axis focused on scientific research, consisting of three courses of research in physics and one of seminars, so the student is able to learn to learn, developing skills and values.

c) Human Sciences: The National Curricular Guidelines for Ethnic-Racial Relations in Education, for the Teaching of History, Afro-Brazilian and Indigenous Culture [29, 30], for Environmental Education Policies [31, 32] and for Human Rights Education [33] are discussed in the Ethics and Philosophy of Science, and Humanism and Religious Culture courses and are also covered in other courses and activities of the course. The Libras course is offered as an elective course in the program [28].

d) Biological Sciences: Anatomy and physiology are approached together in the human morphophysiology course. There is no specific course for biochemistry in the curricular matrix, however, the contents are approached in another course.

e) Undergraduate Thesis: research work, presented as an article or a thesis. Research work is a part of a project in the of Professional Practice MF I course, and is elaborated during the Professional Practice MF II course

PPC B: The program is structured with basic, advanced and specific nuclei, organizing the contents according to their complexity and enabling a multi and interdisciplinary development. The axes are divided by areas of knowledge: Exact Sciences, Biological and Health Sciences, Human and Social Sciences, and Medical Physics Sciences.

a) Exact Sciences: Calculus and Analytical Geometry I and II and a course dedicated to solid state physics. Two digital signal analysis courses are also offered. Note the absence of a specific course for analytical mechanics. Instrumentation, general or applied chemistry, and programming are not also addressed by specific courses.

b) Area of Specific courses: like PPC A, the three major areas are divided into specific courses, with practical activity, which can provide, in addition to the extracurricular experience, a first contact with professional practices. There is a course on image processing in medical physics and physics of medical images. There is no specific course on physics of non-ionizing radiation, which might be embedded in the course of physics of radiation.

c) Human Sciences: there are courses on entrepreneurship, accessibility and health management, courses that provide the understanding on the entrepreneurial academic development, on people with disabilities, work, health and social life and the principles of management of health systems and services " (PPC of University B).

Based on [28] the course of Libras is a compulsory elective course. Aspects of Education of Ethnic-racial Relations, Education of History and Afro-Brazilian and Indigenous Culture, Policies of Environmental Education and Education in Human Rights [29, 30, 31, 32, 33] are diluted throughout the offered courses, two courses related to ethics: Bioethics and Ethics and Professional Exercise in Medical Physics. Health Education courses are also offered, addressing educational practices and methodologies. English I and II courses enable the student to be in contact with the language. Moreover, there are courses on History of Health Sciences and Academic Writing and Scientific Methodology.

d) Undergraduate Thesis: it is the elaboration of a scientific article in the area the student's choice in agreement with their counselors.

PPC C: the basis of the curricular matrix is basic general and humanistic training nuclei and specialized training nucleus.

a) Exact Sciences: there is a greater distribution of the courses of calculus (going from I to IV) and electromagnetism (divided in I and II). The matrix includes classical and analytical mechanics, a course on scientific programming language, general chemistry and Introduction to Electronics, in which students can extend their knowledge on "the physical foundations of electronics, semiconductors devices and practical applications ". There is no specific course on solid state physics, which may be included in the discipline of Physical Foundations of Ionizing Radiation Detectors. The content of digital signal analysis can also be inserted in the context of other courses of the matrix.

b) Area of Specifics: the Radiological and Sectional Anatomy course is highlighted, in which different methods of image acquisition are studied, such as conventional radiology, mammography, densitometry, magnetic resonance, among others. The three major areas have their content divided into three corresponding courses, as in matrices A and B. Likewise the matrix of course B, there is no specific discipline for non-ionizing radiations.

c) Human Sciences: The Libras course is mandatory and the contents of Education of Ethnic-racial Relations, Education of History and Afro-Brazilian and Indigenous Culture, Policies of Environmental Education and Education in Human Rights are approached in the discipline of Ethics and Citizenship [29, 30, 31, 32, 33]. This area also includes the courses of Anthropology and Franciscan Cosmovision and, as in PPC B, the course of Scientific Methodology.

d) Undergraduate Thesis: consists of writing a scientific article, in the area chosen by the student in agreement with their advisors.

PPC D: The course is divided into exact and biomedical sciences, having a common core or basic courses and interdisciplinary courses.

a) Exact Sciences: there is a strong emphasis on artificial intelligence and programming, with four dedicated courses (based on C programming) and a course dedicated to the analysis of digital signals. This matrix also includes a general chemistry course and two algebra courses: Vector and Matrix Algebra and Linear Algebra. Calculus is taught in four courses, likewise in A and C matrices. Two instrumentation courses are also predicted, one of which is aimed at the hospital area.

b) Area of Specifics: contents related to the three major areas of medical physics are divided in two imaging courses: Biomedical Images and Acquisition of Biomedical Images, while the radiation physics course, as in curriculum matrix A, is divided into non-ionizing and ionizing.

c) Human Sciences: likewise, matrix B, there are courses of entrepreneurship, health management, English, and Reading and Production of Science Communication Texts. The program offers a course on Bioethics, Philosophical Anthropology and Techno-science, and the student can also choose to study Latin America and Social Sustainability, Afro-descendants in Latin America, or Indigenous Peoples in Contemporary Latin America. Libras is an optional course.

d) Biological Sciences: the matrix contains two biophysics courses, one of which is focused on ionizing radiation and a general one.

e) Undergraduate Thesis: Production of a thesis, being structured in two courses: Conclusion I and II, consisting of a work in the area of student choice, being a project or a case study.

The following chart shows the distribution of hours in different teaching areas:

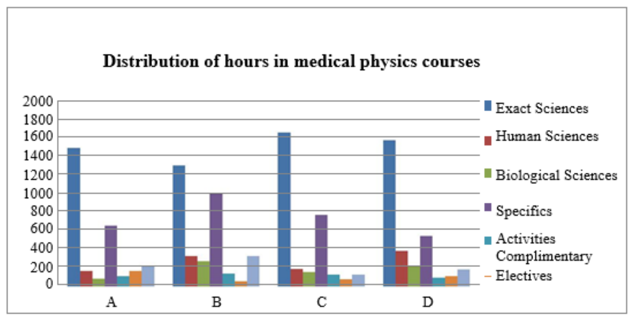

FIGURE 1. Comparison of medical physics programs in Rio Grande do Sul state by workload.

Analyzing Graph 1, one can see the program with the highest workload in exact sciences is course C with 1836 hours, followed by program D with 1740 hours, A with 1650 hours and B with 1440 hours. The greater number of courses and workloads in exact sciences for all programs agree with the DNCs for the Physics Programs, since there must be a common axis with a strong base in physics and mathematics. In the human sciences area, program D has the highest workload, with 420 hours, followed by program B with 360 hours, program C with 204 hours, and program A with 180 hours. The program with the highest biological sciences workload is B with 300 hours, followed by program D with 240 hours, and programs C and A with 170 hours and 90 hours, respectively. It was noted that for the specific subjects, the highest workload is found in PPC B with 1110 hours, followed by C with 850 hours, A with 720 hours, and lastly, D, with 600 hours. Complementary activities consist of attending scientific events, short courses, conducting academic research, among others. The highest workload for those activities is in program B with 150 hours, then C with 136 hours, followed by A with 120 hours, and D with 100 hours. Elective courses are a set of extra courses offered by the university, from which the student can choose the most relevant to study. The student, in this context, decides about his learning. The highest workload is found in the matrix of program A with 180 hours, followed by program D with 120 hours, C with 85 hours and B with 60 hours. The last item compared is the workload of the supervised internship (final stage of the course), where the highest workload is in program B, with 360 hours of practice, followed by A with 240 hours, D with 200 hours and finally the C with 136 hours.

Internationally, AAPM's Report 197 and the IAEA document, namely "The Medical Physician: Criteria and Recommendations for Academic Training, Clinical Training and Certification in Latin America" [3, 6, 7], provides specific content that should be incorporated into the programs of residency and improvement in medical physics in the world. For comparison, we verified which contents are present in the curricular matrices of the programs as subjects, and the results are presented in the following table. The analyses were made through the study of the syllabus of each course arranged in the curricular matrix of the PPCs and the definitions of each content present in the international documents. The bias of the comparison is based on the absence of more specific data on the content taught in each course, since the knowledge can be taught within one or more courses and not explained in the syllabus, which is a general overview of the program to be taught. It is suggested that a more detailed study should be carried out covering the teaching plans for the courses.

TABLE IV. Predicted contents by international documents that are included in the curricular matrices as courses in the medical physics programs in Brazil (marked with an X).

IAEA/AAPM	*Curricular Matrix PPC A*	*Curricular Matrix PPC B*	*Curricular Matrix PPC C*	*Curricular Matrix PPC D*
Radiation Physics and Dosimetry	X	X	X	X
Radiation Protection	X	X	X	-
Fundamental of Image in Medicine[1]	X	X	-	X
Radiobiology	X	X	X	X
Anatomy and Physiology	X	X	X	X
Computational Methods[2]	X	-	X	X
Ethics	X	X	X	X
Mathematical Methods[3]	X	X	X	X
Security[4]	-	X	-	X
Clinical Research[5]	X	X	X	X
Scientific Communication[6]	X	X	X	X
Radiodiagnosis[7]	X	X	X	-
Nuclear Medicine[7]	X	X	X	-
Radiotherapy[7]	X	X	X	-

1. Within the subjects evaluated in the documents the keywords for comparison with the syllabus were image sciences and processing of images. 2. Compared with the search for courses in PPCs with the title and syllabus related to theory, language or programming methods. 3. According to international documents, all the exact sciences courses that consider physical and mathematical formalism have been considered. 4. Subjects were considered to embrace safety teaching in both the use of apparatus and practices. 5. Both courses directed at the scientific production and the courses of Undergraduate Thesis. 6. Courses of scientific methodology and textual production were considered for comparison. 7. Only the specific courses for each area were considered. In PPC D the contents of the three areas are diluted within the specific disciplines offered.

V. FINAL CONSIDERATIONS

From this study, it was possible to establish a profile of the four programs of Medical Physics of Rio Grande do Sul. Through the analysis of the contents present in the PPCs, the programs are in agreement with the regional and national needs and are connected to the philosophy of the respective institutions. Teaching-learning methodologies are innovative; however, an in-depth evaluation is suggested to evaluate the application of the techniques and methods, which can be done through daily study in institutions or through interviews with teachers and students. In the curricular axis, there are diverse training scenarios, with contents of the curricular matrices in harmony with all the characteristics of the philosophy of the institutions. However, there is a bias in the study of these curricular matrices: the information about all the contents presented in the courses is arranged in the respective teaching plans and not in the syllabi, and may imply in a mistaken perception that some contents are disregarded in the matrix. That can be corrected by accessing these documents and conducting a new comparison between programs as well as DNCs and international documents. Other factors that will also bring greater completeness to the study are the analysis of the method of assessment of each course and the profile of teacher training.

The relevance of this work is evinced by the questioning of the training model of the students who start the medical physics program. The obtained information can be incorporated into their structure, always seeking to build a professional profile that is increasingly multi and interdisciplinary, and capable of acting according to the reality of Brazil. Cooperation will strengthen the pillars of the profession, and for this, a strong foundation from the beginning of the career is essential. Finally, the study will continue for the analysis of the PPCs of the other States of the country.

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