An overview of physics and physics teaching in Brazil: Physicists, physics teachers and physics licensure programs

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Abstract. This paper is part of a study that aims to present a panorama of the teaching of physics in Brazil, contributing to the memory of physics teaching in this country. It also aims to support research of greater amplitude, to be carried out in the future in other member countries of IUPAP (International Union of Pure and Applied Physics). In this part of the study, data from several sources were considered, among others, Brazilian Society of Physics (BSP), the Brazilian Institute of Geography and Statistics (IBGE), the Nacional Institute of Pedagogical Studies (INEP) and the Ministry of Education and Culture (MEC). Due to the wide range of information obtained and the multiple possibilities of analysis, we chose to explore and interpret part of the data here and, for that matter, we used documentary analysis only. The data analyzed allowed us to establish, for example, relationships between the number of students attending high school in Brazilian public schools, the number of licensed teachers who work in these schools in each state of the country. These data also allowed us to link with data from the literature on the subject, which consider the causes of teaching avoidance and undergraduate courses in Physics, aggravating factors for the precarious situation of the medium level physics teaching in the country.

1. Introduction
A more systematic concern with teaching and research in physics education in Brazil began to take shape in Brazilian universities in the 1960s. The first dissertations and theses on the subject, and the subsequent appearance of the first national event on teaching, the National Symposium on Physics Education (I SNEF), held at the Institute of Physics of the University of São Paulo (IFUSP), took place in 1970. The decisions taken by this Symposium, promoted and organized by the Brazilian Society of Physics (BSP) were extensive. One of them was the edition of the first periodical in the area in 1979: the Journal of Physics Teaching (Revista de Ensino de Física), according to authors who have researched the factors that contributed to the origins of research in the field [1-2].

In this study, we have looked for general information on the teaching of Physics in Brazil in order to produce an updated panorama. This panorama presents data about the main activities developed in the field of Physics Teaching, the approximate number of physicists and physics teachers working in the country, journals, events and teacher education programs in the area. This study can answer questions, for example: What is the ratio between the numbers of physicists in a state or region in Brazil, compared to the number of physics teachers? What does that mean? Our current system of training physics teachers is according to the basic school necessities? What is the dropout rate of students in our degree courses in physics? The answers to these questions are important to set out ways for the improvement of physics teaching, to be shared to policy makers, as well as to propose new studies on this subject. We also intend, in the future, to extend the study to other physics societies, in 60 other countries that are now members of the International Union of Pure and Applied Physics (IUPAP). The research has the support of the...
BSP’s Board of Directors, through its Secretariat for Teaching Affairs, which provided a document to the researchers in order to facilitate the collection of data from various sources. In addition to the data from the BSP, other data were obtained from institutions such as the Brazilian Ministry of Education and Culture (MEC), the Brazilian Institute of Geography and Statistics (IBGE), and the National Institute of Pedagogical Studies (INEP). Thus, we understand that the data collected in this study can work as reference material for future actions of the aforementioned institutions or, at an academic level, to value Physics and its Teaching, thus reducing the disparities and challenges that arise for this area in the country.

2. Methodology
Due to the diversity of consulted sources, the collection was carried out in various stages. We highlight below some of the steps already completed. We started with a survey of studies already carried out in the Brazilian literature on Physics. This review has not yet exhausted all the data that we consider necessary for this study, but it is already robust, considering that it includes important scholars. For example, authors who have carried out studies on the memories of the teaching of Physics in Brazil [1-2], authors who are responsible for databases of theses and dissertations on physics [3] or science teaching in Brazil [4], authors who have conducted studies on the physics education (licensure) programs in the country [5-6], and others who have done research on the advancement of postgraduate studies in science and physics in recent decades [7-8]. We also included in this survey authors who discuss topics such as the professional choice of licensed graduates and bachelors in Physics [9], and the dropout in physics education undergraduate programs [10].

The second stage is a documentary analysis of collections available in several official bodies, such as the Brazilian Society of Physics (BSP). Their Board and Secretariat for Teaching Affairs, in addition to supporting the study, provided general related data of professors and teachers associated with BSP. Through this data, we have been able to learn, for example, the number of physicists and their options for the different areas of physics, as well as their distribution throughout Brazilian states. The documentary analysis was also carried out with public agencies such as IBGE (Brazilian Institute of Geography and Statistics), INEP (National Institute of Pedagogical Studies) and MEC’s portal (Ministry of Education and Culture). Data are currently being collected from universities, research institutes and state education secretariats. These data have been collected by physicists invited to participate in the research. For the collection of these data, a questionnaire was prepared and validated to be completed with the data collected from the aforementioned bodies. This validation occurred in a presentation of the questionnaire to GPEC (Research Group on Teaching Sciences) of the UNESP, after a presentation of the questionnaire, researchers, and master’s and PhD students, among others, contributed to the final version of this questionnaire.

3. Data analysis
To better understand the analysis of the data below, it is important to highlight some aspects of Brazil and its educational system. Brazil is a federative republic, formed by the union of 26 federal states, 5,570 municipalities and the Federal District, Brasília, the country's capital. According to the Brazilian Institute of Geography and Statistics (IBGE) the estimate of the population of Brazil, having as reference July 1, 2019, is 210,147,125 people. These data were published in the Federal Official Gazette of August 28, 2019. The municipalities are a territorial constituency with legal personality and with a certain administrative autonomy, being the smallest autonomous units of the Federation. Each municipality has its own Organic Law that defines its political organization, respecting the provisions of the Federal Constitution and the State Constitution of the State in which it is located. Figure 1 below show the Brazilian states and their populations.
### Figure 1

a) Political map of Brazil, b) Estimate of Brazil's population on July 1, 2019

The structure of the Brazilian educational system is defined by the Law of Directives and Bases of Education - Law No. 9.394 of 1996 (LDB) - and by the general guidelines of the Federal Constitution of 1988, which determines that basic education is a right of all citizens. These guidelines authorize government spheres to conduct and maintain educational programs, which are designed based on the Common National Curriculum Base (BNCC). This Base ensures that all students have access to basic and indispensable knowledge, regardless of where they came from or their conditions of study. Together, it is up to the Union, the States, the Federal District and the Municipalities to plan, finance, maintain and execute teaching policies that are in accordance with the BNCC, the LDB and the constitutional guidelines. The LDB, in turn, defines that there are two categories of education: basic education and higher education. Mandatory basic education - that is, it is the duty of parents or guardians that children and adolescents complete basic education, just as it is the duty of the State to provide this education. It consists of the following modalities: Early Childhood Education: duration of 4 years, with students from 0 to 3 years old; Pre-school: duration of 3 years, with students from 4 to 6 years old; Elementary School: duration of 9 years, with students from 6 to 14 years old; High School: duration of 3 years, with students from 15 to 17 years old; Technical High School: schools that offer technical courses during off-school periods - which are extra-class periods - for their students. The duration is variable and can be from 1 to 3 years. There is also the modality called Youth and Adult Education (EJA), which serves individuals who have not had the opportunity to attend elementary or high school at the expected age; Education in the Countryside, which offers education to individuals who live far from urban centres, in the so-called rural areas; and Special Education, which serves students with special needs.

Higher Education is comprised of undergraduate, graduate (master's, doctoral and post-doctoral) and distance learning (distance education) at universities. This modality fits male and female students who have completed high school, who are generally over 17 years old. In Brazil, a wide variety of courses are offered in different areas of knowledge, having different durations. Some of these courses can even

### Table: Federation Unity Population (2019)

| Federation Unity | Population (2019) |
|------------------|------------------|
| Acre             | 881,935          |
| Alagoas          | 3,337,357        |
| Amapá            | 845,731          |
| Amazonas         | 4,144,597        |
| Bahia            | 14,873,064       |
| Ceará            | 9,132,078        |
| Distrito Federal | 3,015,268        |
| Espírito Santo   | 4,018,650        |
| Goiás            | 7,018,354        |
| Maranhão         | 7,075,181        |
| Mato Grosso      | 3,484,466        |
| Mato Grosso do Sul | 2,778,986     |
| Minas Gerais     | 21,168,791       |
| Pará             | 8,602,865        |
| Paraíba          | 4,018,127        |
| Paraná           | 11,433,957       |
| Pernambuco       | 9,557,071        |
| Piauí            | 3,273,227        |
| Rio de Janeiro   | 17,264,943       |
| Rio Grande do Norte | 3,506,853     |
| Rio Grande do Sul | 11,377,239   |
| Rondônia         | 1,777,225        |
| Roraima          | 605,761          |
| Santa Catarina   | 7,164,788        |
| São Paulo        | 45,919,049       |
| Sergipe          | 2,298,696        |
| Tocantins        | 1,572,866        |
| Brasil           | 210,147,125      |

(Source: IBGE)
be taken at a distance - distance education mode. Higher level courses are optional. This means that the State is not obliged to guarantee that all citizens attend this modality, but it must guarantee - according to the Constitution - free and public access to it.

The training of teachers for basic education, according to LDB, takes place at a higher level, in a degree course, with a full degree, in universities and higher education institutes. As of 2007, all teachers must be qualified at a higher level and all higher education courses must meet national guidelines for their functioning. In the case of degrees, these must comply with the National Curriculum Guidelines [11] for the Initial Training of Teachers for Basic Education and the Common National Base for the Initial Training of Teachers of Basic Education (BNCC).

Teacher training presupposes the development, by the licensee, of the general competencies provided for in the BNCC, as well as the essential learning to be guaranteed to students, regarding the intellectual, physical, cultural, social and emotional aspects of their training, with a view to full development of people, aiming at Integral Education.

The licensee – future teacher - is required to develop the corresponding general teaching skills, as well as the specific skills and the skills corresponding to them. Specific skills refer to three fundamental dimensions: They are: a) professional knowledge (mastering the objects of knowledge and knowing how to teach them; demonstrating knowledge about students and how they learn; recognizing students' life contexts; and knowing the structure and governance of educational systems); b) professional practice (planning teaching actions that result in effective learning; creating and knowing how to manage learning environments; assessing the development of the student, learning and teaching; and conducting the pedagogical practices of the objects of knowledge, skills and skills); c) professional engagement (committing to one's own professional development; committing to student learning and putting into practice the principle that everyone is capable of learning; participating in the school's Pedagogical Project and building democratic values; and to engage, professionally, with families and the community, in order to improve the school environment.

The training of teachers for Basic Education, is organized in three groups, with a total workload of the degree courses must have a minimum of 3,200 (three thousand and two hundred) hours, and must consider the development of the professional skills mentioned above. Group I: 800 (eight hundred) hours, for the common base that comprises scientific, educational and pedagogical knowledge and bases education and its articulations with systems, schools and educational practices; Group II: 1,600 (one thousand and six hundred) hours, for learning the specific contents of the BNCC areas, components, thematic units and objects of knowledge, and for the pedagogical mastery of these contents; Group III: 800 (eight hundred) hours, pedagogical practice, distributed as follows: 400 (four hundred) hours for the supervised internship, in a real work situation at school, according to the Pedagogical Course Project (PCP) of the training institution; and 400 (four hundred) hours to practice the curricular components of Groups I and II, distributed throughout the course, since its beginning, according to the PCP of the training institution.

We emphasize that the process of establishing the pedagogical practice must be carried out through prior formal adjustment between the training institution and the associated or associated institution, with preference for schools and public institutions. The pedagogical practice must be accompanied by a teacher from the training institution and by 1 (one) experienced teacher from the school where the student performs it, with a view to the union between theory and practice and between the training institution and the field of activity. The practice must be present throughout the licensee's training path, with the participation of the entire teaching team of the training institution, and must be developed in a progression that, starting from the initial familiarization with the teaching activity, leads, in a harmonious and coherent way, the supervised internship, in which the practice must be engaged and include the mobilization, integration and application of what was learned in the course, as well as being aimed at solving the problems and difficulties experienced in previous years of study and research.

The data already collected and presented in Table 2 permit to draw graphs such as the Graph 1 below, in which it is evident that the ratio between the number of students at public secondary school level and
the number of physics teacher education programs (called licensure in Brazil). It shows that the ratio is more expressive in the states of Bahia, Pará, São Paulo, Mato Grosso and Ceará, in this order.

Table 1 is an attempt to relate gathered data in Brazil. It relates a number of elements and can be used for various analyses (Sources: [12-15]).

Table 1. Number of students in secondary school, physics teachers working in secondary schools, physicists associated with Brazilian Society of Physics (BSP) and physics education programs (licensure in physics) for each state in Brazil.

| Brazilian State      | Number of students in public secondary schools within public education | Number of Physics Teachers in secondary schools within public education | Number of physicists (According to the Brazilian Society of Physics) | Number of physics teacher education programs (Licensure in Physics) |
|----------------------|-------------------------------------------------------------------------|------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|
| Acre                 | 60,916                                                                  | 113                                                                    | 6                                                                   | 1                                                                   |
| Alagoas              | 42,573                                                                  | 27                                                                    | 123                                                                | 2                                                                   |
| Amazonas             | 22,461                                                                  | 912                                                                   | 92                                                                  | 6                                                                   |
| Amapá                | 196,480                                                                 | 121                                                                   | 12                                                                  | 1                                                                   |
| Bahia                | 364,418                                                                 | 1686                                                                  | 465                                                                | 5                                                                   |
| Ceará                | 39,163                                                                  | 2053                                                                  | 351                                                                | 5                                                                   |
| Federal District     | 66,772                                                                  | 310                                                                   | 235                                                                | 4                                                                   |
| Espírito Santo       | 319,656                                                                 | 487                                                                   | 160                                                                | 3                                                                   |
| Goiás                | 142,710                                                                 | 1196                                                                  | 215                                                                | 8                                                                   |
| Maranhão             | 379,866                                                                 | 1661                                                                  | 147                                                                | 11                                                                  |
| Minas Gerais         | 361,851                                                                 | 3931                                                                  | 923                                                                | 19                                                                  |
| Mato Grosso do Sul   | 140,772                                                                 | 587                                                                   | 65                                                                  | 3                                                                   |
| Mato Grosso           | 126,545                                                                 | 897                                                                   | 96                                                                  | 2                                                                   |
| Pará                 | 122,495                                                                 | 872                                                                   | 190                                                                | 4                                                                   |
| Paraíba              | 81,179                                                                  | 529                                                                   | 224                                                                | 6                                                                   |
| Pernambuco           | 835,089                                                                 | 2129                                                                  | 376                                                                | 6                                                                   |
| Piauí                | 129,409                                                                 | -                                                                     | 128                                                                | 5                                                                   |
| Paraná               | 570,450                                                                 | 2297                                                                  | 573                                                                | 9                                                                   |
| Rio de Janeiro       | 591,882                                                                 | 3587                                                                  | 1659                                                               | 11                                                                  |
| Rio Grande do Norte  | 1,885,281                                                               | 440                                                                   | 221                                                                | 6                                                                   |
| Rondônia             | 235,288                                                                 | 315                                                                   | 21                                                                  | 2                                                                   |
| Roraima              | 357,808                                                                 | 93                                                                    | 35                                                                  | 3                                                                   |
| Rio Grande do Sul    | 457,620                                                                 | 2300                                                                  | 528                                                                | 10                                                                  |
| Santa Catarina       | 95,205                                                                  | 1289                                                                  | 233                                                                | 10                                                                  |
| Sergipe              | 247,506                                                                 | 282                                                                   | 146                                                                | 2                                                                   |
| São Paulo            | 1,802,429                                                               | 11067                                                                  | 3416                                                               | 20                                                                  |
| Tocantins            | 110,189                                                                 | 544                                                                   | 24                                                                  | 2                                                                   |
Figure 2. Ratio between numbers of students in (public) secondary schools per number of physics licensure programs in Brazil. Sources: [11]; [14]

Figure 2 shows also that the lack of physics licensure programs is clear in some states. However, there are points to be highlighted: one of them is the fact that São Paulo, being the state with the largest number of physics licensure programs in the country, still has a high student-licensure ratio. We observe that, even with so many licensures, São Paulo still presents a higher demand for teachers than Roraima, Paraíba, and the Federal District among others. Despite that, it is not possible to say, based on the available data, what is the ideal number of licensure programs for a particular number of students. Even so, it must be noted that it should have been possible to see greater homogeneity in this graph, i.e. student-licensure ratios should be more similar across states, and the bars have nearly the same height. Still, only these data are not sufficient to show which states would require more investments in teacher training since the number of openings, undergraduates and individuals who remain in the field in each program (licensure) might vary.

The data also show, for example, the small number of licensures in several states of the country, such as Acre, Amapá, Alagoas, Mato Grosso, Roraima and Tocantins, when compared to data from the Southeastern and Southern regions, where the following states are located: São Paulo, Santa Catarina, Rio de Janeiro and Rio Grande do Sul. In order to complement this information, we have built Figure 3.

Figure 3. Ratio between the number of (public) secondary school students and physics teachers in Brazil.
We note that data on the number of licensed teachers were obtained from the Brazilian Schools Census [13], and data on student numbers were taken from INEP’s Brazilian Schools Census [12].

Before the analysis itself, some additional comments are necessary. During data collection, the number of teachers in the state of Piauí was not available due to an internal error in the official website. The Ministry of Education was informed of the problem but did not fix it in time for the comparison shown here. The second additional remark refers to the state of Alagoas, which presented the ratio of one teacher for 3,848 students, which would have made the other bars very small and negatively affect the readability of the graph. Thus, the first thing to note is that the number of licensed teachers does not correspond to the number of licensed physics teachers, but rather the number of licensed individuals in any area who act as physics teachers.

As can be seen in the graph, most bars are within a good range of 100 and 300 students per teacher, which is not a large number. Considering that in Brazil there are two classes a week (one hour each), and thirty-five students in class, teachers are responsible for about three to nine classes, which represents a reasonable workload in the routine of a teacher. Even so, there are states where there should be more licensed teachers, such as Acre, Pará and, especially, Alagoas, where one teacher for 3,848 is a very bad ratio. That represents almost one teacher for every one hundred classes, so it is emphasized here that this state needs more investments to improve the working conditions for the teacher, since the ratio between licensure programs and students is similar to that of the other states. That probably means that dropout from the program is high, the demand is low and that many professionals give up the teaching career, which indicates that changes are necessary in teacher education/training so that Alagoas can have enough teachers to meet the needs of physics lessons. Confirming what has been said here, data in the dissertation defended by Kussuda [10] show that educating more graduates, as in the case of the state of São Paulo, does not guarantee that we have more teachers in the classroom.

Physics is present in the curriculum of all basic education in Brazil and therefore all secondary school students take this subject, which makes these numbers even more worrying and begs for the question: how is it possible to improve education if we do not even have the minimum number of licensed teachers in the right field to teach those lessons?

As regards the importance of knowing physics and science in general, given the need for scientific and technological literacy nowadays, how will it be possible to improve the teaching of physics without at least enough professionals? Thus, it is essential to remember the importance of working conditions and training so that there is increased demand for the licensure program in physics and, consequently, the search for the physics teaching profession.

4. Final considerations

The data collected and partially analysed in this study still need to be considered in greater depth, considering the limitations highlighted above. However, they are important data for a first approximation in answering the research questions to meet the objectives of this study, which is still in a state of consolidation. The data, such as the table above and the graphs drawn from them, make clear that our system of training physicists and physics teachers is still precarious and is far from what the country demands, both in basic and higher education. Although higher education institutions have a share of responsibility in the issue of undergraduates’ dropping out of licensure programs in this discipline, the lack of consolidation of the career of basic education teachers in Brazil is clear. Such a consolidation will have to take into consideration what teachers need to live, including adequate salaries and work conditions in order to deal with challenges that otherwise may cause education professionals to quit. These are also the responsibility of other instances of state or federal administration, i.e., they require actions by agents other than the university.

Deeper investigation in this study calls for new sources of information as well as a more profound analysis of the data that still need to be collected, more refined treatment of those data, as well as the completion of the survey together with states education secretariats, for example.

There are important issues that come out of the study, which need further research analysis. For example, to find out the licensed individuals in any area who act as physics teachers; or to understand
the effectiveness of “licensed teachers” and the “licensed physics teachers”. How are they combined in the structure of Physics Education in Brazil? Other diagrams using mathematical notation could also be drawn like the ratios students/physicist, students/physics licensure programs to cite some of them. A more refined analysis of the data should be able to show details like these and others. The expansion of the study to include other countries, with the support of institutions such as IUPAP, should also assist in the refinement of the data considered at the national level as far as they are compared, in the future, with different scenarios in other countries.

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5. References
[1] Nardi R 2005 Science teaching research in Brazil: factors that determined its constitution and characteristics according to Brazilian researchers (Associate Professor Habilitation Thesis, State University of São Paulo – UNESP, Bauru, Brazil) p 170
[2] Nardi R 2006 Memories of Science Education in Brazil: the Physics Education research Investigações em Ensino de Ciências 10(1) 63
[3] Salem S 2012 Profile, evolution and perspectives of research in teaching physics in Brazil (PhD Thesis in Physics Education, University of São Paulo – USP, São Paulo, Brazil) p 385
[4] Megid Neto J 1990 Research in physics teaching in high school in Brazil: conception and treatment of problems in theses and dissertations (Master’s Degree Thesis, State University of Campinas – UNICAMP, Campinas, Brazil) p 296
[5] Gebara S T and Garcia J R B 2007 Physics degrees at Brazilian universities: a diagnosis of the initial training of physics teachers Revista Brasileira de Fisica 29(4) 519
[6] Castiblanco Abril O L 2013 A structure for teaching didactics of physics in initial teacher education: contributions from research in the area. (PhD Thesis in Science Education, State University of São Paulo – UNESP, Bauru, Brazil) p 276
[7] Feres G G 2010 Graduate studies in Science Education in Brazil: a reading based on Bourdieu's Theory (PhD Thesis in Science Education, State University of São Paulo – UNESP, Bauru, Brazil) p 337
[8] Nardi R 2014 Memories of Science Education in Brazil: the constitution of the area according to Brazilian researchers, origins and advances in graduate studies Revista do IMEA-UNILA 2(2) 13
[9] Kussuda S R 2012 Professional Choice of Physics Graduates from a public university (PhD Thesis in Science Education State University of São Paulo, Bauru, Brazil) p 184
[10] Kussuda S R 2017 A study on dropout in a Physics Degree course: discourses by alumni and professors (Master’s Thesis in Science Education, State University of São Paulo, Bauru, Brazil) p 308
[11] Brazil. Ministry of Education 2019 Resolution CNE/CP #2, December 20, 2019. Defines the National Curriculum Guidelines for Initial Teacher Education for Basic Education and establishes the Common National Base for Initial Teacher Education for Basic Education (BNC-Training) Diário Oficial da União Section 1, pp 87-90.
[12] Brazilian Institute of Geography and Statistics (IBGE) 2016 Projection of the population of Brazil (Brasília, Brazil). Access: http://www.ibge.gov.br/apps/populacao/projaco/
[13] Ministério da Educação (MEC) 2007 Teacher Census (Brasília, Brazil) Access: http://portal.mec.gov.br/plano-nacional-de-formacao-de-professores/ceso-do-professor
[14] Brazilian Society of Physics (n.d.) (São Paulo, Brazil) Retrieved from http://www.sbfisica.org.br
[15] Castiblanco Abril O L and Nardi R 2014 Interpreting the curricular structure of Brazilian undergraduate programs in Physics, from an epistemological perspective of the Didactics of Physics Revista Electrónica de Investigación en Educación en Ciencias 9 54