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Article

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Formação para a inovação nas Ciências Biológicas: análise de disciplinas e percepção dos egressos

Training for innovation in Biological Sciences: Subject analysis and perception of graduates

Formación para la innovación en Ciências Biológicas: análisis de asignaturas y percepción de egresados

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Resumo: Este estudo buscou identificar se a formação de mestres e doutores da grande área Ciências Biológicas os prepara para atuar com inovação. Trata-se de um estudo descritivo e exploratório com abordagem metodológica qualiquantitativa. Foram analisadas as disciplinas oferecidas nos programas de pós-graduação desta grande área, assim como as respostas de 5.186 egressos a um questionário sobre a formação profissional nas pós-graduações brasileiras. Os resultados apontam a existência de iniciativas e exemplos de sucesso relacionados a inovação e empreendedorismo no ambiente acadêmico, mas estes parecem ser exceções. Em geral, os programas ofertaram poucas disciplinas, atividades e iniciativas para preparar os estudantes a atuar com processos e ambientes de inovação.

Palavras-chave: pós-graduação; inovação; mestres e doutores.

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Abstract: This study sought evidence that the training of masters and doctors in the field of Biological Sciences prepares them to work with innovation. It is a descriptive and exploratory study with a qualitative-quantitative methodological approach. The subjects offered in the graduate programs of this broad field were analyzed, along with the responses of 5,186 graduates to a questionnaire about their professional training in Brazilian graduate programs. The results suggest that while there are initiatives and successful examples of innovation and entrepreneurship in the academic environment, these cases appear to be exceptions. Overall, the programs offered few subjects, activities, and initiatives to prepare students for working with innovation processes and environments.

Keywords: Graduate programs; innovation; masters and doctors.

Resumen: Este estudio buscó evidencias relacionadas con la formación de maestros y doctores en el amplio campo de las Ciencias Biológicas para trabajar con innovación. Se trata de un estudio descriptivo y exploratorio con un enfoque metodológico cuali-cuantitativo. Se analizaron las asignaturas ofrecidas en los programas de posgrado de este amplio campo, así como las respuestas de 5.186 graduados que respondieron un cuestionario sobre su formación profesional en programas de posgrado brasileños. Los resultados indican la existencia de iniciativas y ejemplos exitosos relacionados con la innovación y el emprendimiento en el entorno académico, pero estos parecen ser excepciones. En general, los programas ofrecieron pocas asignaturas, actividades e iniciativas para preparar a los estudiantes para trabajar con procesos y entornos de innovación.

Palabras clave: programas de posgrado; innovación; maestros y doctores.

1 Introduction

Higher education has undergone numerous transformations since the establishment of the first universities. These changes, which pertain to the responsibilities of these institutions, were referred to as the "Academic Revolution" by Christopher Jencks and David Riesman (1968). The first of these changes took place in the 19th century, when universities embraced a new mission: Conducting research alongside their existing responsibilities of preserving and maintaining knowledge and teaching. The second change occurred around the 1970s when universities took on an additional mission: To actively engage in economic and social development (Etzkowitz, 1983).

In Brazil, universities underwent a significant reform in 1968, integrating teaching and research activities. This reform was modeled after U.S. research universities, featuring departments and research institutes, credit systems, and full-time professors and students. The teaching profession was formalized during this period, and master's and doctoral degree qualification went on to be required for university professor hiring and promotion (Balbachevsky, 2011).

A few funding institutions were crucial for sustaining and expanding teaching and research activities in Brazil. At the federal level, the Coordination for the Improvement of Higher Education Personnel (CAPES) and the National Council for Scientific and Technological Development (CNPq) are prominent. Established in 1951, both have played a fundamental role in promoting research and training qualified human resources. They offer scholarships, incentives for creating graduate programs in various fields, fund scientific and technological research, and support the infrastructure of research institutions and universities.

In particular, concerning innovation efforts in Brazil, the establishment of the Financier of Studies and Projects (FINEP) in 1967 is noteworthy. FINEP is a public company and acts as the executive secretariat of the National Science and Technology Fund (FNDCT). Since its inception, FINEP has been responsible for providing financial support and promoting priority programs and projects for the scientific and technological development of Brazil. It offers funding to various players in the broad science and technology network, including research institutions, universities, government agencies, NGOs, and companies that transfer resources, both public and private, at the national, state, and municipal levels (Silva, 2011).

However, it was primarily in the mid-2000s that there was a notable increase in public policies, programs, laws, and other instruments designed to support innovation in Brazil. Among other objectives, these initiatives aimed to encourage universities to take on a more active role in engaging with the productive sector, in addition to expanding their teaching and research activities (Maculan; Mello, 2009).

Despite the efforts, fostering innovation in these environments has been challenging. Developing open and flexible institutions that prioritize entrepreneurial activities and actively seek effective collaboration between academia and industry remains a difficult task. (Dalmarco; Hulsink; Blois, 2018). The scope of this new scenario necessitates new organizational structures, as it impacts the objectives, values, and practices that dominate these institutions.

Despite government initiatives aimed at fostering an environment conducive to innovation, Brazil still faces numerous challenges in becoming an innovative nation. Despite having a favorable science, technology, and innovation infrastructure, and although there are a few successful cases of technological innovations in Brazil (Suzigan; Albuquerque, 2011), Brazilian companies show weak competitive performance across all segments with high added value and high technological content. With few exceptions, Brazilian competitiveness is strong only in activities related to commodities with large production scales and low added value. These activities, which are energy-intensive and dependent on natural resources, do not significantly contribute to job creation and innovation (Cassiolato; Szapiro, 2015; Morceiro; Guilhoto, 2023).

In this context, the importance of promoting innovation-related policies and initiatives within higher education stands out. These efforts, aligned with public policies to promote innovation in the country, are already becoming a reality. The most recent National Education Plan (NEP) (Brazil, 2014) included goals and strategies to encourage the training of human resources for innovation at both undergraduate and graduate levels within higher education institutions (HEIs) and science and technology institutions (STIs). The latest National Graduate Studies Plan (NGSP, an integral part of the NEP) emphasized the importance of collaboration between academia and the business world, stating that graduate studies should aim to: "[...] promote a talent development agenda to support innovation processes within the country's industrial sector [...] enhance the skills and competencies that drive global competitiveness" (CAPES, 2010, p. 193).

Hence, there is a focus on the necessity of training human resources to engage with technological advancements and broaden opportunities linked to innovation within the country. Therefore, a few questions are pertinent: Are Brazilian professionals who have the potential to develop new technologies aware of the legislation, instruments and environments that are being created? Are they aware of methods that

enable the application of their research findings? Are they interested in or seeking to establish relationships with institutions that work with technologies but do not have primarily academic purposes, such as industries or hospitals?

These and other inquiries motivated this study, which aimed to ascertain whether students graduating from Brazilian graduate programs (GPs) got professional training that motivated them to work in innovative environments. Additionally, the study sought to determine if these graduates were interested in applying their research results, whether in traditional academic settings or elsewhere, aligning with the profile of the innovative scientist as proposed by Etzkowitz (1998).

To gather evidence that addresses the driving questions, this study examines the training of scientists in graduate programs using two sources: The curricula offered and the perceptions of graduates from programs in the broad field of Biological Sciences that were active at CAPES in 2019. It is important to highlight that the GPs in this far-reaching area are distributed across four areas of assessment: Biological Sciences I, Biological Sciences II, Biological Sciences III, and Biodiversity.

The choice of the major field of Biological Sciences for study is justified by several aspects: (a) It is one of the most established fields within the National Graduate System, with programs operating since the system's inception; (b) It is the field that trains the youngest masters and doctors in the country; and (c) Graduates from this area take longer to secure formal employment compared to other fields (Center for Management and Strategic Studies – CMSS, 2016). These graduates have the potential to develop impactful technologies that can address various issues related to sectors crucial for societal well-being and the foundation of sustainable development in the country. These sectors include education, environment, bioeconomy, health, and defense (CAPES, 2017; Brazil, 2016).

2 Methodology

This study is organized into two groups of analyses. The first provides details on the subjects offered in the curricula of all academic and professional Biological Sciences GPs, while the second brings insights from masters and doctors who graduated from these GPs with regard to the training of scientists in Brazil.

A total of 312 GPs were identified in the broad field of Biological Sciences (subdivided into the areas of Biological Sciences I, II, III, and Biodiversity) in the CAPES Open Data Platform as active and accredited by CAPES in 2019. That year, 67 programs offered only academic master's degree (AM) courses, 17 professional master's degree (PM) courses, and 228 offered academic master's and doctoral degree (AM/AD) courses. Details about the active subjects of these programs were gathered manually

on the Sucupira Platform (CAPES Collection), in the "Disciplinas" (Subjects) field, and organized in an Excel file.

Using the content analysis method outlined by Bardin (2011), the course syllabi were examined and categorized into three main thematic categories: (i) Natural and Health Sciences, (ii) Human and Social Sciences, and (iii) Exact and Earth Sciences. Details of this classification are available in Medeiros and Leta (2020) and Medeiros (2020). For the present study, only the subjects within the category "Human and Social Sciences" are of interest, specifically those related to the subcategory "Management, Politics, and Economics."

These subjects were reclassified into three new thematic groups based on the topics covered in their syllabi:

a) Entrepreneurship and Innovation: The subjects specifically addressed these topics, for example: "Topics in intellectual property and innovation in health" and "University-corporation relations in innovation,"

b) Science and Technology (S&T) Management and Dynamics: The subjects covered aspects of the dynamics of the scientific activity, without specifically referring to the topics covered in the previous group, for example: "Dynamics of scientific production and assessment," and "Public Administration and the role of the manager," and

c) Social Aspects, Legislation and Public Policies: The subjects dealt with specific topics on socio-environmental and/or socioeconomic aspects, and/or discussed current laws and public policies or with a historical bias, for example: "Brazilian Environmental Policy" and "Brazilian legislation applied to fauna, population and microbiological management."

The second group of results features information about the perception of graduates. The data were gathered in 2019 using a structured online questionnaire, which was organized into three sections and included 12 closed questions and one open question.

Distributed by means of the SurveyMonkey platform, the questionnaire included questions about the students' perceptions of various aspects of scientist training in graduate programs in Brazilian Biological Sciences. The Free and Informed Consent Form (FICF) was sent along with the questionnaire and was included in the project submitted to and approved by the Research Ethics Committee of the Federal University of Rio de Janeiro's Clementino Fraga Filho University Hospital (CFFUH) on May 12, 2017, under CAAE case number 67792917.8.0000.5257.

Data from graduates who responded to the questionnaire were obtained from spreadsheets available on the CAPES Open Data Platform (2018), which included the e-mail addresses of students who defended their theses or dissertations between 2013

and 2017. After the data were cleaned and standardized, 25,385 records of graduates with their respective contact information remained. The message containing the link to the questionnaire was sent to each of the graduates. In all, 13,326 graduates actually received the message (52.4% of the total) of whom 5,186 opened the link and responded to the questionnaire (38.9% of the total). Of the 5,186 respondents, 373 partially completed the questionnaire. These partial responses were recorded and included in the analyses.

Descriptive statistics were used to analyze the objective questions, focusing on absolute and relative frequencies (percentages). These analyses were performed using the Tableau 2022.4 software, which was also utilized to generate the figures.

The spontaneous accounts from the graduates underwent thematic content analysis (Bardin, 2011), specifically focusing on topics related to innovation, entrepreneurship, and related subjects, which were selected for this study. To ensure confidentiality, account authorship is anonymized using abbreviations representing the area (CBI, CBII, CBIII, or BDV), the academic degree of the respondents (M for Masters or D for Doctorate), and the region of Brazil where they completed their graduate studies (N for North, S for South, NE for Northeast, SE for Southeast, CO for Midwest).

3 Results and Discussions

This section presents the profile of subjects related to the theme of Innovation offered by GPs in the major field of Biological Sciences in 2019. It then explores the perceptions of masters and doctors who graduated from these GPs regarding scientist training in Brazilian graduate programs, as well as their opinions about their own experiences in these environments.

3.1 Subjects offered in the GPs curricula

In previous studies, Medeiros and Leta (2020) and Medeiros (2020) categorized the 13,407 subjects offered by Biological Sciences GPs into three macro categories, one of which was "Human and Social Sciences," comprising 1,633 subjects (12% of the total). In this macro category, the authors included a group of 260 subjects called "Management, Politics, and Economics," which were offered by only 72 GPs (23% of the total).

This section, therefore, focuses on subjects deemed relevant for training professionals qualified to engage in entrepreneurship and innovation processes (Faix; Mergenthaler, 2015; Henrique; Cunha, 2008; Kisgen, 2017). To provide a clearer and more detailed representation of the content offered in this group of subjects, the syllabi were categorized into three thematic groups, as described in the Methodology. Table 1 shows the distribution of these subjects in these groups, also indicating whether they

are elective or required, in addition to the areas and levels of the GPs that were analyzed. The color saturation in the cells indicates the concentration of subjects: The greater the number, the greater the saturation.

One notable aspect is that 248 subjects (95.3% of the total) are not mandatory, meaning they are not part of the minimum required subjects for students to obtain their diplomas. Also significant is the concentration of these subjects in GPs in the Biodiversity area, which offer 155 subjects (59.6% of the total), and in GPs offering both Master's and Doctorate degrees (M/D), which have 180 subjects (69.2% of the total).

Regarding the three thematic groups, the group "Social Aspects, Legislation, and Public Policies" has the highest number of subjects (offered in 36 programs), followed by the group "S&T Management and Dynamics" with 86 subjects (offered by 46 programs), and, finally, the "Entrepreneurship and Innovation" group, with 83 subjects (offered by 33 programs).

Table 1 – Number of subjects in "Management, Politics and Economics" offered by GPs in the broad Biological Sciences area, according to the thematic group, the obligation, the area, and the academic level of the program. 2019.

Thematic groups			CAPES Area / Level										
			BDV			CBI			CBII		CBIII		Over all total
			AM/D	AM	PM	AM/D	AM	PM	AM/D	PM	AM/D	PM	
Required	No	Social aspects, legislation and public policies	60	9	11	1			1	3	2		87
		S&T management and dynamics	40	15	11	1			5	6	4		79
		Entrepreneurship and innovation	3	1		19	1	1	35	15	4		79
	Yes	Social aspects, legislation and public policies	2		1						1		4
		S&T management and dynamics	1	1						1		1	4
		Entrepreneurship and innovation							1	2		1	4

Note: AM - Academic master's degree; M/D – Academic Master's and Doctorate; PM – Professional Master's Degree.

Source: Own preparation with data from the Sucupira Platform (2023).

The subjects in the "Social Aspects, Legislation, and Public Policies" group cover topics that enable students and graduates to engage in initiatives and decision-making related to social issues influenced by science and technology activities. This aligns with the university's mission to train individuals who are committed to addressing social issues (Dias; Serafim, 2009). Despite the social importance of these subjects, they are predominantly offered in Biodiversity programs, with only two instances where the subject is required.

The subjects in the "S&T Management and Dynamics" group are also predominantly found in Biodiversity programs, with 68 subjects offered, 66 of which required. Seven Biological Sciences II, three Biological Sciences III, and one Biological Sciences I program also offered at least one elective subject on this topic. Additionally, only one Biological Sciences II and one Biological Sciences III program offered one required subject. This result was surprising, considering graduates will need to manage activities such as people, projects, finances, and laboratories. However, few programs offer subjects that can assist them with these tasks.

Regarding this group of subjects, it is important to note that although most were offered by Biodiversity programs, there was little variety in their content, with the majority focusing on environmental management topics. Other subjects related to management, which are crucial for the professional training of scientists and higher education teachers (Botomé; Kubo, 2002), were rarely offered.

Finally, the subjects in the "Entrepreneurship and Innovation" group have a different distribution profile, being primarily offered by Biological Sciences II programs (16 GPs), with 53 subjects, and Biological Sciences I programs (12 GPs), with 21 subjects. Two specific programs were responsible for the largest offering of subjects on this topic within the CBII group: The Master's and Doctorate program in Technological Innovation and Biopharmaceuticals, and the Professional Master's program in Technological Innovation and Intellectual Property, both at the Federal University of Minas Gerais. The limited availability of this group of subjects in other GPs indicates a misalignment between program curriculum planning and public policies supporting innovation, particularly the NEP and the NGSP, which emphasize this topic within the higher education system.

Despite this misalignment, it is important to note that the provision of subjects is just one of the foundational aspects that define the graduate environment, through which students aim to broaden and solidify their knowledge during their training (Botomé; Kubo, 2002; Trzesniak, 2004). Extracurricular activities, such as lectures and seminars, along with other formal and interpersonal aspects of the graduate environment—mediated by relationships, the pressures experienced during the course, and engagement in other activities—are also key factors in the training of scientists (Botomé; Zanelli, 2011).

Therefore, to gain a deeper understanding of the graduate environment and of the entrepreneurial aspects of scientist training, a questionnaire was distributed to students who completed graduate studies in Biological Sciences. The goal was to analyze their perceptions regarding the training they received and the program environments throughout their academic journey. The following section presents the results and discussions of these analyses.

3.2 Graduates' perception of their professional training in graduate programs

To gauge the perception of the 5,186 graduates who partially or fully responded to the questionnaire, we included the sentence "During your graduate studies, were you encouraged to" followed by various activities. These activities encompassed those related to basic research, such as preparing scientific articles and seeking partnerships with other academic institutions, as well as those related to applied research and technological innovation, such as finding solutions to societal problems, preparing and filing patents, and establishing partnerships with companies and technology innovation centers.

The graduates' perceptions (whether positive or negative) regarding the encouragement they received for each of these activities were assessed based on the level of agreement they indicated: Greater agreement reflected a more positive perception. Figure 1 illustrates a summary of the results for this question, displaying the percentage distribution of responses based on the degree levels of the respondents' programs.

The results indicate that graduates realize that they were especially encouraged to conduct activities related to basic research, in particular to "prepare and publish scientific articles", since, on average, 72 percent completely agreed with the statement. Interestingly, 79.6 percent of professional master's graduates totally agreed or tended to agree that they received incentives to prepare and publish scientific articles. This observation is somewhat contradictory, as professional GPs were established with the goal of training individuals to apply knowledge, technologies, and scientific findings to solve real-world problems (Silva; Del Pino, 2017). Conversely, disseminating results in scientific journals is a hallmark of basic research activities (Meadows, 1974), a tradition in personnel training within Brazilian academic programs (Cavalcanti; Pereira Neto, 2014).

Regarding applied research and technological innovation activities, the graduates' perceptions are negative, with an average of 43 percent completely disagreeing that they were encouraged to prepare and file patents, seek partnerships with companies, and familiarize themselves with technology innovation centers or agencies. Such activities are indispensable for contemporary higher education, since HEIs are considered a source of entrepreneurship, technology and innovation,

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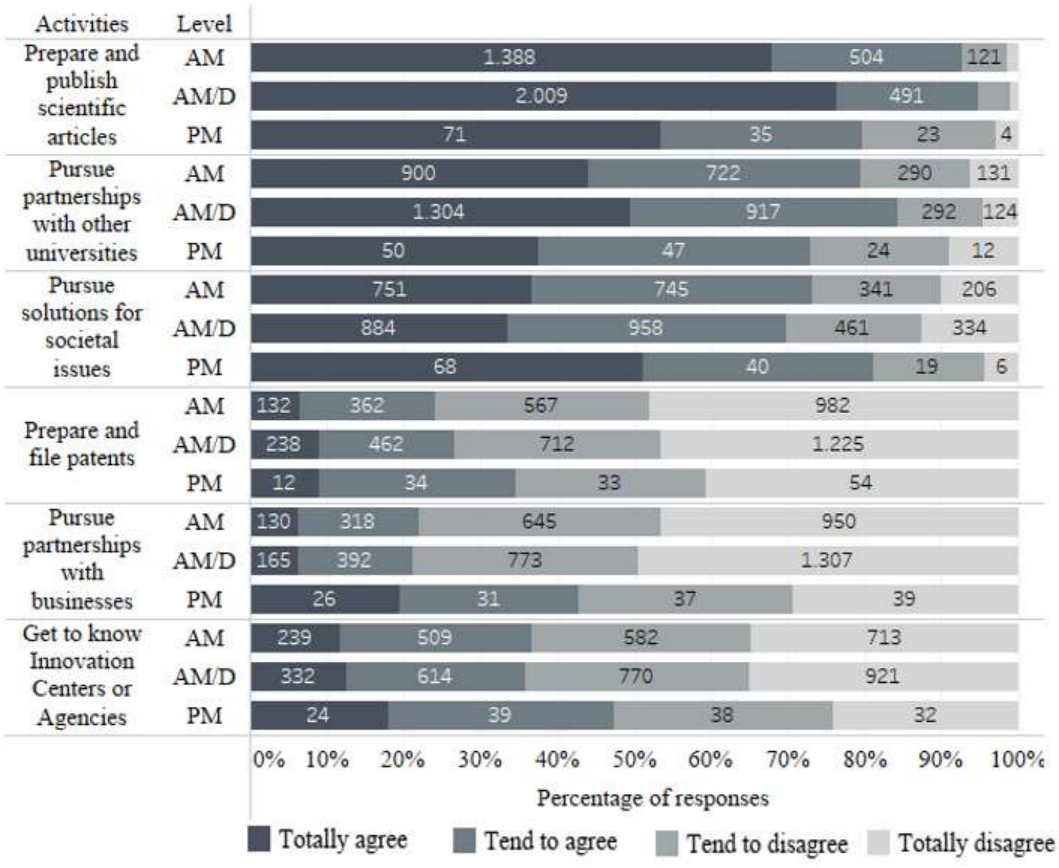
dedicated to critical research, education, preservation and renewal of the cultural heritage (Etzkowitz, 2013; Martins; Assad, 2008).

On the other hand, respondents reported that they were encouraged to seek "solutions to society's problems." This observation is intriguing and seemingly contradictory, as the practical application of knowledge produced for society, particularly in the experimental sciences, relies on additional activities related to technological innovation, such as patent creation and seeking partnerships between companies. However, graduates reported receiving little encouragement in these areas. It is possible that, when responding to the question, graduates only considered a potential future application of their research. However, their lack of preparation to apply the results of their research at the time of answering the questionnaire highlights a training gap. They would have to proactively seek out ways to apply their findings on their own initiative.

Figure 1 – Distribution of answers to the question "During your graduate studies, were you encouraged to" by students graduating from graduate programs in Biological Sciences. 2019.



Source: Own preparation (2023).

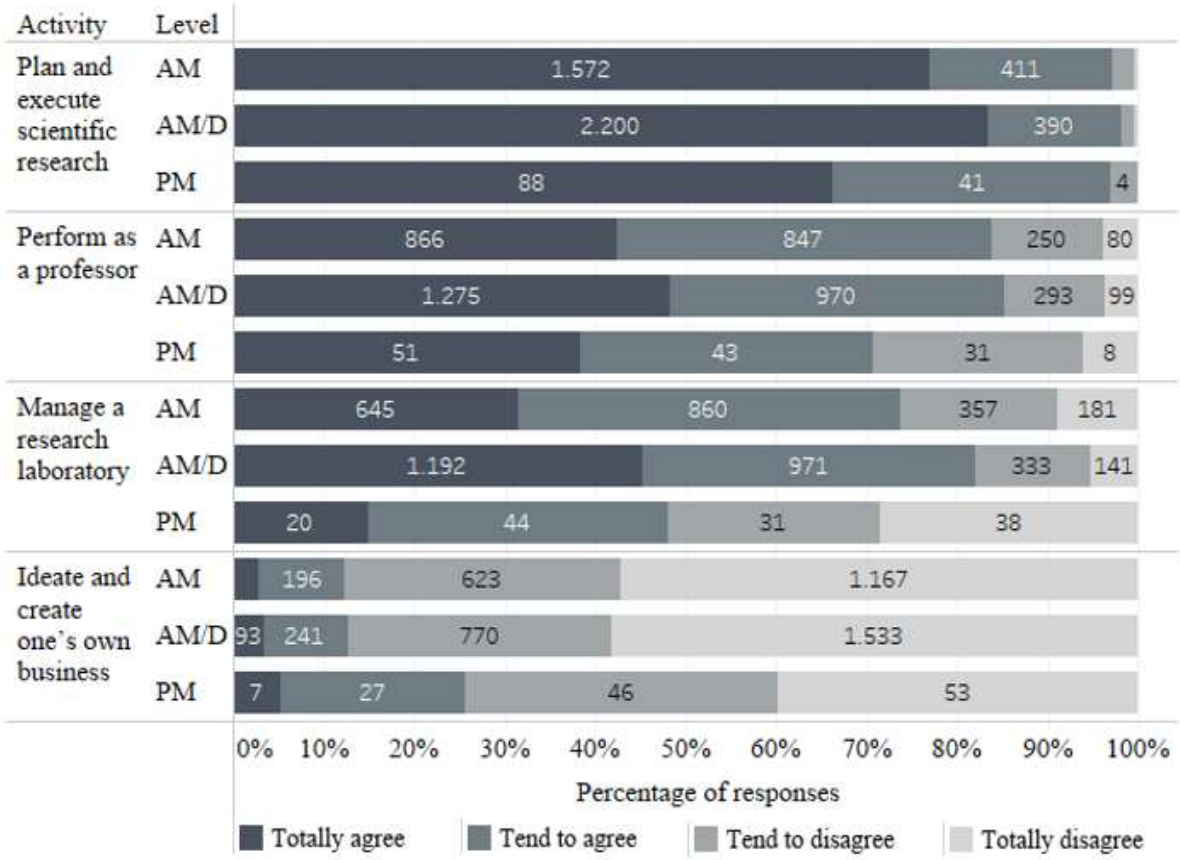
Another question, “Did the training you received in your graduate course prepare you to” aimed to understand graduates' perceptions regarding the preparation they received during their graduate courses for certain activities related to research (planning and conducting scientific research, managing a research laboratory), teaching (working as a teacher), and entrepreneurship (developing and launching their own business). These options were selected according to the main activities conducted by scientists in Brazil, mainly focusing on research and teaching (Botomé; Kubo, 2002; Moreira; Velho, 2012) and with the more recent approach of the “innovative scientist” (Etzkowitz, 2013; Mergenthaler, 2015).

Figure 2 shows the percentage distribution of responses according to the respondents' highest degree level. It is evident that the majority of graduates have a positive perception that they were prepared to "plan and conduct scientific research." This perception likely reflects the nature of the field, which requires practical activities and a routine that demands substantial training and empirical work experience. Conversely, graduates are less emphatic and positive about the preparation they received for managing a laboratory, a responsibility shared by many scientists working in the experimental field. This perception is clear when considering the smaller percentage of respondents who completely agree, indicating a training gap. In practice, it is likely that graduates will need to manage laboratory-related activities among their professional responsibilities (Ramos; Velho, 2013).

Regarding training for teaching, the data indicate that a significant fraction of graduates completely agree that they were prepared to teach. This analysis indicates that a significant number of graduates have a positive perception, feeling that they have received adequate training to engage in teaching activities. This aligns with the Law of Guidelines and Bases of National Education in Brazil (Brazil, 1996), which states that the training of future university professors should primarily occur in master's and doctoral programs.

Finally, preparing for activities related to ideating or starting one's own business was where graduates expressed the most negative perception, with an average of 57.2 percent disagreeing that they were prepared for this aspect. This observation aligns with the demand for training innovative professionals (Faix; Mergenthaler, 2015) and underscores the underdeveloped nature of GPs in Biological Sciences concerning entrepreneurship and innovation. This is further supported by the limited availability of subjects related to these themes, as highlighted in the first section of the results.

Figure 2 – Answers to the question: "Did the training you received in your graduate course prepare you to":



Source: Own preparation (2023).

3.3 Graduates' opinions on the professional training of scientists in Brazil

In addition to sharing their views on the training they received in their master's and/or doctorate programs, graduates were asked to provide their opinions on the professional training of scientists in Brazil. This topic was explored using an open-ended question: "Leave a comment here about professional training in Biological Sciences graduate programs in Brazil (optional)," where respondents could freely share their opinions on the professional training of scientists in the country. The results are presented below.

3.3.1 Spontaneous accounts

Of the 5,186 respondents, 1,609 made spontaneous accounts, 257 of which made some mention of topics analyzed in this work. Below, we highlight several themes, including subjects and activities related to innovation, concerns and difficulties regarding entering the job market, and we illustrate them with original excerpts from the accounts.

Including **subjects and other activities related to technological innovation and entrepreneurship** in the scope of graduate studies is essential for the training of professionals capable of working in innovation processes (Etzkowitz, 2013). This topic frequently attracted negative perceptions and criticisms in the graduates' spontaneous accounts. These accounts highlighted not only the limited availability of subjects, but also a lack of activities that encouraged or supported entrepreneurship or professional preparation for working in innovative environments, whether in academia or other fields.

> There are few subjects available that focus on preparing scientists for entrepreneurship. Such subjects could teach and encourage graduate students to use the knowledge obtained during their studies to develop their own businesses (CBIII). D. SE.).

> I believe that graduate studies should begin to broaden the range of career options beyond academia. We are so focused on being scientists that we have no subject related to entrepreneurship, scientific dissemination, management and environmental consultancy, just to give a few examples. (BDV. D. N.).

> Professional training in graduate courses in biological sciences in Brazil still has a teacher training profile. The lack of teaching on own business management is practically unanimous, considering that graduate-level professors aim for publications and there is no talk of possibilities of guaranteeing anything more than teaching. (CBIII. AM.NE.).

On the other hand, there were also positive accounts highlighting experiences offered and encouraged by universities related to this topic. A few comments mentioned the presence of innovation environments organized within universities, while others referred to specific initiatives by professors. Although these professors did not work directly with entrepreneurship or innovation, they recognized the importance of the topic and sought to present it to students, either independently or by inviting guest speakers. As in the following accounts:

> [...] Innovation and entrepreneurship is a new course taught by professors who, although not specializing in the subject, recognize its importance. They strive to offer 50 openings annually to students from all graduate programs at the university [...]. (BDV. AM. S.).

> The department linked to the graduate program where I was trained has an incubator for biotechnology companies, in addition to promoting lectures on entrepreneurship and patents. (CBII. D. S.).

> In terms of training, graduate studies still fall short in areas related to industry, particularly clinical research. Among the innovation incentives, all were recommended by university centers and not directly by the graduate program. (CBIII. D. SE.).

A study by CAPES, analyzing data from graduates of graduate programs in strategic fields, revealed that "areas with a strong research focus," like Biological Sciences, often tended to show lower rates of graduates entering formal employment.

(CAPES, 2017). These data may also be explained by the lack of alignment between public policies aimed at expanding the training of highly qualified personnel and those focused on promoting the absorption of this workforce by the local labor market. Such policies should provide professional and personal opportunities that are commensurate with the qualifications of graduates (Pádua et al., 2018; Ramos; Velho, 2011).

These facts seem to be well known by Biological Sciences graduates, who reported their concern and **difficulties in entering the job market** after completing their master's and doctorates. The following stood out among these cases: (1) The significance attached to entrepreneurial knowledge, which, although having multiple meanings (Almeida et al., 2013), was extensively discussed in the context of establishing one's own business, and (2) the significance of collaborations between universities and companies, exemplified by the following instances:

> My training was extremely focused on my research project and on publishing articles. Only during my doctorate, when I was co-supervised by a professor from University X[1] (I graduated in the interior of Rio Grande do Sul), was when I started to change my views from being a student to being a professional. I believe that graduate students should be encouraged to be professionals, not just students. They should be encouraged to pursue patents and even start their own businesses. After all, the job market cannot accommodate everyone, and not everyone possesses the skills or opportunities to pursue an academic career. (D. BDV.S.).

> I am halfway through my doctorate, linked to a Federal Public University. However, I undertake my experiments in a public/private company, Embrapa. This partnership was crucial for my learning with regard to projects, collaborations with other national/international companies, patent development, and so on. Therefore, I find it very compelling to have more public policies that promote such partnerships [...] (CBI. M. SE.).

In this study, 36 percent of respondents (1,872 individuals) reported having had some form of international experience during their graduate school training. Some spontaneous accounts included information about this type of experience, either during or after completing their courses. The comments had a tone of comparison between the foreign environment and the environment of Brazilian programs, although the specific location outside Brazil was not always mentioned. Overall, the accounts emphasized positive experiences abroad, including aspects such as entrepreneurship, application of research findings, and preparation for non-academic job markets, among others. Such as, for example, in the following accounts:

> [...] as I experience a different reality abroad, I tend to compare it with the training I am getting here. Finally, today I understand the difference between a university that prepares graduate students for the market and one that does not. I am in a place with a high rate of postgraduate employability, and I would say that the main difference is that here the university encourages

[1] The name of the university was concealed to ensure the confidentiality of the account.

> students to create a career plan from the first graduate class. Students also have access to various resources throughout their education to help them move forward with their career plan, such as business fairs where companies set up stands at the university and explain career possibilities and even recruit interns or make hires. [...] (BDV. AM. CO.).

> Training provided in Biological Sciences in Brazil is inadequate in preparing students for the job market. I am working at a University abroad, and here they have an entire department to guide doctoral students into the job market, from courses to networking with former students who are now working in companies or academia. (D. BDV.NE.).

Despite the numerous challenges and difficulties related to entrepreneurship and innovation discussed in previous accounts, some respondents shared insights into their direct involvement or current work in these areas, as illustrated in the examples below:

> I had the opportunity to receive excellent graduate training (master's and doctorate) and completed a seven-month postdoctoral internship in Germany. But I was unable to enter the job market working in my area of doctoral training; however, I work as a biologist in another area: Production of mushroom mycelia in a laboratory and urban production of edible and medicinal mushrooms. It is my own business and is still in its development phase. (CBII. D. NE.).

> [...] graduate courses should also focus on teaching and innovation, supporting recent doctors, including, to develop their own consulting and innovation businesses, with a more objective return to society and its issues. This has been my current focus. I have founded an environmental consulting company that is currently in the incubation process at UFPR. The company aims to address environmental issues, providing a return on the investment that society makes in the university. It also facilitates the development of parallel projects with students and those graduating from graduate programs [...]. (D. BDV.S.).

The collection of accounts suggests that, despite the limited inclusion of entrepreneurship and innovation topics in the curricula of Biological Sciences graduate programs, there are initiatives in these environments to promote these themes. Additionally, there are graduates who engage in entrepreneurial activities and participate in Technological Innovation-related endeavors. Moreover, innovation centers and agencies within university settings are highly significant. Even without specific efforts from graduate programs to educate and raise awareness among students about these subjects, these environments are recognized for promoting initiatives in this regard. They serve as a hub for training and information for students interested in the topic.

4 Concluding Remarks

The purpose of this study was to gather evidence related to the education of professionals at the highest level of higher education in Brazil (master's and doctoral levels) in the broad field of Biological Sciences, which is considered strategic for national development. We sought to answer the following research question: Do Brazilian GPs in Biological Sciences train qualified professionals to work in the environment conducive to innovation that the government has been striving to create? To address this, the study analyzed the subjects offered in graduate programs (GPs) and the responses to a questionnaire regarding the graduates' perceptions on this topic.

Insofar as the subjects were concerned, it was noted that there was limited—sometimes even nonexistent—availability, particularly of non-required subjects that are considered crucial for the training of professionals qualified to work in innovation. These subjects typically cover areas such as management, economics, public policies, and legislation. Since the subjects are crucial for building knowledge, skills, and professional competencies (Faix; Mergenthaler, 2015; Santos et al., 2009), it was expected that there would be a greater availability of content related to innovation. This expectation stems from the fact that the main instruments guiding national higher education (NEP and NGSP) emphasize the importance of training professionals to work in this field.

In addition to analyzing the subjects, to gain a deeper understanding of the environment in which master's and doctoral students were being trained, we investigated, through responses to the questionnaire, whether other activities or forms of encouragement were being implemented in graduate programs. Graduates generally expressed a positive perception regarding the encouragement and preparation they got for activities related to basic research and teaching. However, their perspective was less positive when it came to activities related to applied research and work in non-academic environments. Therefore, for many of these graduates, graduate training appeared to have neglected other essential activities, crucial even for the effective execution of their research in the academic environment. These activities include project management, for instance, and the training of professionals capable of directing their efforts toward technological development and innovation.

Finally, the spontaneous accounts underscored the students' limited exposure to initiatives aimed at preparing them to work in innovation processes or environments. The respondents' criticism regarding the absence of subjects, activities, encouragement, and preparation for entrepreneurship and innovation highlights a gap in these areas. However, it can also be seen as a positive sign that students are aware of these topics, even though the graduate programs are not addressing them. Moreover, the examples of experiences abroad, seemingly in environments more

conducive to engaging students in these issues, are quite enriching. Graduates express concerns about the gap in preparation for innovation between these countries and Brazil, which serves as a cautionary note, and perhaps even as inspiration, for the network of contacts remaining in the country. This network can drive initiatives to improve the current scenario.

In this context, two key points underscore the need to reconsider activities and incentives related to innovation in graduate programs, especially those that train professionals in strategic sectors facing scenarios similar to those in Biological Sciences. The first point emphasizes the need to enhance the training of qualified personnel who actively participate in technological development and innovation processes, particularly based on the cutting-edge knowledge being produced in Brazilian universities. The second point underscores that while, on one hand, the academic sector cannot (and should not) absorb all Brazilian master's and doctoral graduates, unemployment and difficulties in entering other job markets are already uncomfortable realities. On the other hand, increasing the number of doctoral graduates in the country is still considered a strategic goal for Brazilian economic and social development.

There appears to be no easy solution to this scenario, but addressing it requires a collective effort involving government agencies, the private sector, and universities. In this regard, it is imperative for professors, administrators, and graduate program coordinators to collaborate in fostering a culture that encourages students and graduates to engage in activities beyond academia that also involve science and innovation. This is because the demand for new professionals in these spaces is already incompatible with the supply of opportunities, driving issues ranging from the mental health of students and graduates (Pinzón *et al.*, 2020) to brain drain (Azevedo; Dutra, 2021).

In discussions concerning innovation in academic settings, particularly in universities, conflicts related to the construction and utilization of knowledge often arise. The primary argument is that universities should consistently strive to advance frontier knowledge through basic science. There is a concern that the discourse of academic entrepreneurship might result in activities being influenced and directed by corporations according to their own interests. This study does not intend to argue that graduate training should direct toward a specific type of qualification, rather that the knowledge necessary to develop basic research and applied research should be promoted in Brazilian graduate environments.

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