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ARTICLE

INTEGRATIVE REVIEW ON EDUCATIONAL ACTIVITIES FOR THE TRAINING OF SCIENTISTS

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ABSTRACT: The training of scientists is a long-term social investment that contributes to society through the construction of knowledge that can be applied to urgent societal issues. Training scientists requires the mobilization of various chains of social actors. Nevertheless, scientific literature presents numerous reports of experiences from around the world at different institutions that contribute to the development and discussion of scientist training. This study aims to identify and understand the main strategies adopted for training scientists found in the scientific literature. An integrative literature review was conducted between 2003 and 2022, focusing on scientist training, in order to identify and understand the reported experiences of scientist formation. As a result, experiences of interdisciplinary training, methodological capacity-building, internationalization of training, educational management activities, and the incorporation of scientific dissemination into the curriculum are identified as beneficial training practices for aspiring scientists.

Keywords: Scientist training, teaching-learning process, higher education.

REVISÃO INTEGRATIVA ACERCA DAS ATIVIDADES EDUCATIVAS PARA A FORMAÇÃO DE CIENTISTAS

RESUMO: A formação de cientistas é um investimento social de longo prazo, que colabora com a sociedade a partir da construção de conhecimentos científicos que podem ser aplicados na resolução de problemas urgentes. Formar cientistas exige que sejam mobilizadas variadas cadeias de atores sociais, não obstante, a literatura científica nos apresenta diversos relatos de experiência em todo o mundo e nas mais diferentes instituições, que auxiliam no desenvolvimento e na reflexão acerca da formação de cientistas. O presente estudo tem como objetivo analisar as principais estratégias de formação de cientistas apresentadas em tal literatura. Foi realizada uma revisão integrativa da literatura entre os anos de 2003 e 2022, acerca da formação de cientistas, identificando e compreendendo as experiências de formação de cientistas relatadas pelas autorias. Como resultado, as experiências de formação interdisciplinar,

capacitação metodológica, internacionalização da formação, as atividades de gestão educacional e a curricularização da divulgação científica são apontadas como práticas formativas salutares a cientistas em formação.
Palavras-chave: Formação de cientistas, processo de ensino-aprendizagem, ensino superior.

REVISIÓN INTEGRADORA SOBRE ACTIVIDADES EDUCATIVAS PARA LA FORMACIÓN DE CIENTÍFICOS

RESUMEN: La formación de científicos es una inversión social a largo plazo que colabora con la sociedad a través de la construcción de conocimiento que puede aplicarse en la solución de problemas urgentes de la sociedad. Formar científicos requiere movilizar diversas cadenas de actores sociales. Sin embargo, la literatura científica presenta numerosos informes de experiencias de todo el mundo y de diferentes instituciones que contribuyen al desarrollo y la discusión sobre la formación de científicos. El presente estudio tiene como objetivo identificar y comprender las principales estrategias de formación de científicos presentadas en la literatura científica. Se realizó una revisión integradora de la literatura entre los años 2003 y 2022, centrada en la formación de científicos, para fines de identificar y comprender las experiencias reportadas de formación de científicos. Como resultado, se identifican como prácticas formativas saludables para los científicos en formación las experiencias de formación interdisciplinaria, desarrollo de capacidades metodológicas, internacionalización de la formación, actividades de gestión educativa y la incorporación de la divulgación científica en el currículo.

Palabras clave: Formación de científicos, proceso de enseñanza-aprendizaje, educación superior.

INTRODUCTION

The training of scientists is an open-ended social investment involving a complex teaching-learning process that mobilizes various people, resources and institutions (Mojica; Garcia, 2014). Its results go beyond the boundaries of the current generation and have long-lasting impacts.

The exchange of knowledge needed for scientific research, scientific communication, higher education and the job market defines the basic understanding of the training of scientists (Önnerfors, 2007). This is a little-studied subject, usually discussed within postgraduate programs, the academic community and scientific events. There are few scientific papers on the subject (Dias; Serafim, 2009; Voosen, 2015; Antunes; Teixeira; Ferreira, 2020).

Nevertheless, training scientists contributes to the construction of scientific knowledge by providing subsidies for social development, favoring national sovereignty and solving emerging problems. The COVID-19 pandemic exemplifies this issue, since scientific advances and discoveries have been made possible, given the urgency, on a global scale of collaboration and distribution of historical solutions.

As a process, the training of scientists has its privileged place in higher education institutions (HEIs), where teaching, research and extension are based. It is precisely the relationship between teaching and research that lies at the heart of the experience of training scientists around the world, with diverse experiences and activities in the various areas of knowledge.

These experiences can sometimes be reported in scientific communications, collaborating with the teaching-learning process by reflecting on its constituent elements. This begs the question: What are the main strategies for training scientists used in scientific literature?

This study aims to analyze the main strategies for training scientists presented in this literature. To this end, an integrative review of this literature was carried out over a 20-year period (2003-2022) on the training of scientists in multidisciplinary databases. This data was categorized based on the experiences presented and understood using internal categories and their qualifiers.

The importance of this study lies in the systematization of experiences of multidisciplinary approaches in the training of scientists, with a view to informing readers about pro-training actions that can have an active and/or reflective impact on this process.

The results highlight the importance of interdisciplinary, multidisciplinary and translational training; methodological training that interconnects data science, information science and scientific literacy; valuing internationalization experiences; educational management as an aspect of maintaining a diverse and inter-institutional teaching staff; curricularization and scientific dissemination experiences in the process of training scientists.

RESEARCH STRUCTURE, METHOD AND TECHNIQUES

The object of this quantitative study is scientific production on the training of scientists. In this sense, we understand scientific literature as the *corpus* to be systematized and analyzed, which enables us to develop a complex overview of such training, through the integrative review of the literature (Sousa; Silva; Carvalho, 2010).

The integrative literature review enables a critical evaluation and synthesis of the available results on the topic investigated, contributing to the identification of weaknesses and leading to the development of future research (Souza *et al.*, 2017).

To this end, data was retrieved from the centralized databases *EBSCO Search Prime* (with 206 files), *PubMED* (with 19 files), *Scielo* (with 14 files), *Scopus* (with 117 files) and *Web of Science* (WOS) (with 40 files); between the years 2003 and 2022, with the descriptors "training of scientists", "formation of scientists", "formação de cientistas" and "educación de científicos"; refined by "all fields".

The 20-year period (2003 to 2022) was chosen because the retrieval of data on the descriptors did not return a relevant amount of work, even in five multidisciplinary databases, and the period chosen was considered ideal for the historical sample of the discussion, in search of greater sensitivity in the retrieval process (Higgins; Thomas, 2023). The databases were chosen because they had a higher level of updating, organization, internationalization, are considered references as multidisciplinary databases (Walters; Ester, 2003) and are accessible free of charge through the CAPES Periodicals Portal.

Of the 396 files recovered, 3 were removed due to duplication and 1 could not be found. The repetition check was then carried out by comparing the files in the databases. 59 files were excluded, giving a total of 333 files. These files are divided into: 220 articles, 11 book chapters, 33 letters, 21 editorials, 30 newspaper articles, 6 books and 12 abstracts.

The files were then read for classification. A total of 119 files were excluded for: only mentioning the term without any discussion (56 files), not making any reference (47 files), dealing specifically with scientific training (1 file), presenting the term in an institutional affiliation (2 files) and presenting the term only in the references (13 files).

The remaining 214 files were re-read and systematized into categories of analysis derived from the context discussed by the authors, the training of scientists, in order to identify the pro-training of scientists actions that are the substance of our research. We then grouped together data from 139 files that presented actions studied, carried out and analyzed by the authors with pro-scientist training results. The remaining 75 were excluded because they did not deal with the specific topic, but were linked to other aspects of the training of scientists of interest for future studies.

Categorical analysis was chosen for data analysis, as it considers the experiences analyzed by the authors on the object to be relevant data, based on the meaning elaborated and the relationships between the field, unit and organization present in the corpus (Bardin, 1977). This categorization was developed by reading the documents retrieved (139), extracting the excerpts about the pro-scientist training actions in an electronic spreadsheet, comparing these excerpts, grouping them by similarity and generating the frequency (f) which, in an inductive way, was labeled with categories and aligned with qualifiers, derived from the excerpts extracted and compared, in order to qualify these categories by their internal specificities.

These categories are grouped together in a table to show their internal logic. The main category, its internal categories and the qualifications of these categories are accompanied by numbers, which show the frequency (f) with which this data is present in the *corpus*.

These categories (64) are detailed below, considering that the categories (64) and their qualifiers (174) are not isolated, but are formed from multiple determinants that relate to the whole through the object of research.

PRO-TRAINING ACTIONS

The general category "pro-training actions" (see Chart 1) lists the educational processes presented by the authors, which collaborate with the training of scientists, through experience reports, analysis of educational, institutional and training actions. In order to facilitate understanding of the analytical process through the internal categories and their qualifiers, we chose to group these categories into sections.

Chart 1 - Pro-training actions category

Pro-scientist training actions present in discussions about the training of scientists	
Category	**Qualifier**
Careers for scientists (7)	Understanding the career of a scientist in training as a job (3)
	Salaries for junior researchers (2)
	Guarantee research grants for junior scientists (4)
	Discuss long-term career prospects
	Full-time dedication to the training process
	Processes of reflection on a career as a scientist (2)
	Reflect on the social relevance of scientific research (2)
	Building a work and career plan in the process of training scientists
Interdisciplinarity and multidisciplinarity (18)	Contact with frontier areas of the scientific field in the training process
	Scientist training programs must be aware of their disciplinary boundaries so that they can act in an interdisciplinary and/or multidisciplinary way (2).
	Training translational scientists (2)
	Interdisciplinary and/or multidisciplinary training favors the number of student publications

Pro-scientist training actions present in discussions about the training of scientists	
Category	**Qualifier**
Methodological training (16)	Training and support on research methods and techniques (2)
	Practical research design activities (2)
	Promote studies on scientific publishing practices in order to get to know the scientific community
	Value multiple approaches to research objects through a variety of methods and techniques from diverse fields of study (2)
	Scientists should be trained to make evidence-based decisions (4)
	Student-centered approach (3)
	Flexible curriculum based on student needs (4)
	Providing training that takes into account the needs of students
	Guidance must ensure individualized training of scientists (3)
Scientific dissemination (6)	Carry out scientific dissemination activities on social networks
	Scientific dissemination as an intellectual development activity (4)
	Integration and interaction with society through scientific dissemination (3)
	Build relationships with the knowledge they are developing through a reflective process (2)
	Science communication strengthens scientific communication processes
	Scientific dissemination expands the capacity for scientific training
	Science communication contributes to the formation of a scientific community
	The process of training scientists requires communication activities aimed at scientific dissemination (2)
	Development of skills and competencies for content production
	Strengthening links with science journalists (3)
	Science communication content is part of the teaching-learning process
	Thinking up strategies that can link science communication to the subjects in the curriculum
Academic community (3)	Development of an academic community that can support programs to train scientists from the undergraduate level (4)
	Valuing and maintaining an academic community
	Socialization of research results among students and teachers from foreign institutions (2)
	People who have graduated from scientist training programs can advise and support people in the process of training (2)
	Social networks are a great place to build an academic community
	Research groups help to immerse scientists in the training process
Citizen science (5)	Society can be a relevant element in the training of scientists to be incorporated into the process (5)
	Promoting citizen science is part of training scientists
	Scientist training programs need to make society and public authorities aware of the process of training scientists
Educational institution	Infrastructure geared to training needs (6)
	Students in the process of training need to know the multiple possibilities of the institution
	Maintain a technical team in constant dialog, not just for support (4)
	Events with local awards promote the student curriculum as part of the training process (2)
	Training scientists reduces the material costs of research carried out at the institution
	The institutional environment reflects the process of training scientists
	Training activities in laboratories must ensure student safety
	Taking subjects in multiple courses and institutions
	Networking programs helps in the process of solving public problems
Teaching activity	Guidance in training scientists helps academic productivity
	Encouraging co-authorship processes in scientific communication
	Guidance counselors need to reflect on their guidance process
	Development and constant criticism of research agendas
	Organization of placement courses
	Continuing education (6)
Educational management	Inter-institutional teaching staff
	Post-doctorate without mentoring, guaranteeing independence and freedom
	Maintaining information on the scientific policies of governments and agencies (3)
	Lines of research
	Interdisciplinary/multidisciplinary research lines
	Basic research lines that develop into in-depth research lines
	Identify the challenges of training scientists
	Constant feedback on the process of training scientists (4)

Pro-scientist training actions present in discussions about the training of scientists	
Category	Qualifier
Educational management	Revision of the curriculum based on student feedback
	Attention between the dynamics of the curriculum and the hidden curriculum
	Maintaining a portfolio of activities that can be accessed by students in training (2)
	During the process of training scientists, maintain contact with other levels of education (3)
	Selection process
	It must take into account the objectives of training scientists established by the institution (2)
	Bringing in people with different socio-cultural backgrounds contributes to the development of ways of thinking (2)
Training activities	Students can run a scientific journal to understand more about scientific communication
	Specific, short-term training (6)
	Valuing fieldwork for practical application
	Ability to apply the theories developed (2)
	The training of scientists must provide access to technologies and train students in their use and application (6).
	Scientific governance training (2)
	International cooperation, exchange, sharing experiences and technology transfer (10)
	Research ethics training (6)
Scientific literacy (2)	Training must take into account the teaching-learning process of scientific writing (5)
	Techniques for reading articles are part of the process of training scientists
	Knowledge of scientometrics and bibliometrics helps students make decisions about their publications

Source: Prepared by the authors with research data

The following section looks at the most frequent internal categories, as well as correlated internal categories, and lists their qualifiers, seeking context in the analysis of these categories based on the terms and concepts presented in the *corpus*.

INTER-MULTI-TRANS, METHODOLOGICAL TRAINING AND SCIENTIFIC LITERACY

The internal category "interdisciplinarity and multidisciplinarity" (see Chart 1) refers to actions in training contexts that aim, in an applied or theoretical way, to reflect on how science is constructed, in order to provide students with interdisciplinary and/or multidisciplinary experiences in the teaching-learning process.

For the authors, interdisciplinary and/or multidisciplinary training favors the quality of the science built by students, who must have contact with different areas of knowledge (Armutak, 2020). Scientist training programs need to be aware of their disciplinary boundaries in order to operate in the frontier region of knowledge (Armutak, 2020).

The most cited experience is in the field of health, with the training of translational scientists. Translational refers to the relationship between basic science and applied science, in which the discoveries of the former must be translated into actions applicable to the latter, quickly and efficiently, considering the multiple areas of knowledge involved (Byington *et al.*, 2013). In this sense, translational training has a similar scope to evidence-based "areas", but in the sense that scientific research guides action towards application in reality, not just in an advisory/prescriptive way.

These experiences corroborate the idea that the disciplinary training of scientists does not provide a satisfactory answer to the complex questions about reality that are present in our generation (Floriani, 2000). In the pedagogical *praxis of* the training of scientists, the authors therefore reflect on the way in which educational policy is established in the sense of interdisciplinary and/or multidisciplinary training.

The internal category "methodological training" (see Chart 1) refers to training activities for scientists focused on scientific methodology. Based on the idea that scientists in training should be able to make decisions based on evidence, teaching-learning activities aimed at research methods, techniques and design are privileged, through practical and simulated activities.

The authors point to the need for studies on the dynamics of scientific publication, a field of study in information science and data science, in an interface with methodology, so that students have the opportunity to learn methods and techniques in the area of study and also get to know their scientific community and the dynamics of publication (Mendez-Ochaita; Altamirano; Acuna, 2021).

As for the epistemology, ontology and gnosiology required as fundamental for students in the process of becoming scientists (see Chart 1), the experiences are centered on gnosiology. The authors point out the need for multiple research methods and techniques to investigate complex research objects.

Investigating complex problems requires scientists to adopt similarly complex methodological approaches, in the sense that there is no single method for investigating reality (Feyerabend, 1989). The experiences reported point to the need to develop a methodological repertoire that enables understanding of the internal and external dynamics of a research object, making it possible for scientists in training to make decisions about the direction of the construction of scientific knowledge (Duru; Örsal, 2021).

Practical activities involving the application of research methods and techniques, as well as research design/delineation, have contributed to the acquisition, understanding and internalization of an expanded methodological repertoire. Nonetheless, the authors' experiences have focused little on the ontological and epistemological question, reinforcing method, technique and gnosiology as privileged elements in the process of training scientists.

Related to methodology, the internal category "scientific literacy" (see Chart 1) refers not only to the process of structuring and writing, but also to reading techniques and decision-making about scientific publication.

Reading and interpreting scientific literature requires students to use certain techniques that permeate academic culture and the structure of scientific papers. The experiences that corroborate this issue concern structured reading, understanding the sections of each scientific communication and its objectives (Demo, 1992; Carlino, 2017). For this reason, this internal category has a connection with methodology.

Another issue raised, which is connected to the methodology, concerns the mastery of bibliometrics and scientometrics as methods of information science that help students learn about the dynamics of scientific publishing and academic culture. These methods help students make decisions about their scientific communications (Via *et al.*, 2019).

TRAINING, TEACHING AND EDUCATIONAL MANAGEMENT ACTIVITIES

The internal category "training activities" (see Chart 1) refers to the activities carried out by education professionals and their institutions in the process of training scientists.

International cooperation, through technological exchange and transfer, is the main qualifier (see Box 1). These activities are promoted by research programs as an exchange of experience between countries, developing institutional ties and technical-scientific cooperation.

Short-term training (see Box 1), focused on specific elements such as theories and research techniques, are qualifiers that stand out as training actions aimed at meeting the needs of students. While technical training (see Box 1), focused on digital technologies, aims to ensure that students are able to operate and apply technical knowledge capable of fully or partially meeting their information needs related to scientific research.

Research ethics (see Box 1), as an integral part of the process of training scientists, is also a qualifier of these activities, considering that scientists need to have, in addition to technical, scientific and philosophical domains, a formative element aimed at the well-being of the human species in their research process.

The qualifier "training in scientific governance" (see Box 1) is understood as the institutional response between science, politics and society (Via *et al.*, 2019), and concerns scientific accreditation and citizen participation.

Scientists must be close to the community and politics in order to build knowledge that is useful to society, so that people participate in the process of building knowledge, expanding accreditation and its application for a democratic science (Via *et al.*, 2019).

The activities that bring together theory and practice are qualifiers linked to the "ability to apply the theories developed" (see Chart 1), where the aim is to develop *praxis* as a teaching-learning process for training scientists. This *praxis* seeks to transform reality, taking theory as its starting point, which guides practice and the results of these actions, in turn, bring new evidence to theory, developing a cycle of research and application through pedagogical *praxis* (Arzenšek; Kosmrlj; Širca, 2014).

Another activity that translates into a significant experience concerns the management of a scientific journal by students in training (see Box 1). This journal has institutional support, but the management, curation and decision-making actions are the responsibility of the students (Antonius *et al.*, 2007). This experience has had a positive impact on the training of students, making it possible to integrate teaching and research in a practical way, applied to the program for training scientists (Antonius *et al.*, 2007).

As the last qualifier of the internal category "training activities" (see Chart 1), valuing field research as not only a scientific activity, but also a training activity, is an integral part of the process of training scientists and needs to be valued (Viljoen *et al.*, 2004). For the areas of knowledge that need to be involved in field research, the formative activities that involve these experiences help students to better understand the processes of their own research.

As for the "teaching activity" category (see Chart 1), it describes the actions carried out by teachers that corroborate the process of training scientists. Its main qualifier is continuing education, which collaborates with the teacher training process, since it involves the discovery of theories, their organization, revision, deconstruction and reconstruction, in a reflective and practical process of educational activity that ultimately aims to improve the process of guiding and training scientists (Imbernón, 2010).

Leveling courses, a qualifier of the internal category (see Chart 1), have the function of establishing a basis, whether theoretical and/or methodological, for students in the process of training to have a common starting point. These leveling courses are mentioned by the authors, but are poorly described and systematized.

In line with the field of information science, the development and criticism of research agendas (see Box 1) is a qualifier of teaching activity in reflecting on the field of research and its internal and external dynamics.

Research agendas cover the current state of the research field, the research questions, the approaches used to investigate the object of study and are considered fundamental for teachers who guide students in the process of scientific training (Hall *et al.*, 2008). It is important for students to be aware of the current situation in the scientific community and, therefore, teachers need to be up to date on these issues, which should be clarified during the orientation process.

Still in relation to information science, the qualifier for providing co-authorship processes in scientific communication (see Chart 1) concerns the action of professors in their academic contribution networks. The authors argue that greater openness to collaboration and access to networks articulated by researchers have a positive impact on both academic production and the process of training scientists (Twa *et al.*, 2017).

In this sense, the authors consider that, as a teaching activity, there is a need to integrate students into knowledge-building networks, so that they can develop partnerships that can have an impact on the formation and publication of scientific articles.

Reflecting on the mentoring process and contributing to student publications (see Box 1) are internal category qualifiers that are directly linked to this analysis of research agendas and scientific communities.

"Teaching activity" is centered, as an internal category (see Chart 1), on the perception that teaching takes place in guidance, which leads to scientific training in this dual function, research-teaching, with a reflexive approach to teaching activity (Schön, 1992). Nonetheless, the academic structure and educational policy require other organizational functions of teaching, specifically in Brazil.

Teachers in Brazilian higher education are given "teaching" contracts, but end up carrying out teaching, research, extension, cultural and/or management activities. Therefore, being a reflective professional, in the sense of establishing a career focused on research-teaching in a reflective approach, is a challenge considering the multiple activities required by institutions, in which teaching activity is not only connected to guidance and the teaching-learning process.

The internal category "educational management" (see Chart 1) presents another facet of the teaching profession in higher education, which is the contributions made by the management of the institution to the training of scientists.

The main qualifier of this category concerns the search for *feedback* from students about the training process (see Chart 1), based on this constant *feedback*, educational management can revise the curriculum for training scientists. This *feedback*, with a view to change, contributes to the improvement of science education programs, offering the institution material contributions to improve its practices (Via *et al.*, 2014).

The curriculum is not just restricted to issues related to content and institutionality; it encompasses the link between culture, society, institutionality, educational processes, knowledge, theory and possible practices (Sacristán; Neves, 1999). In this sense, discussing the curriculum based on practices, in a participatory way, with a view to criticizing it, puts the curriculum into action as an object of practice to reorient not only the institution, but as a way of reflecting on the process of training scientists.

However, attention must be paid to the dynamics of the curriculum and the hidden curriculum, understood as the curriculum in action. This qualifier points to the need to think of the curriculum not only in a prescriptive way, but based on reality, with a view to offering a "toolbox" so that students in the process of training as scientists can get to grips with techniques, methods and knowledge to solve problem situations (Berling *et al.*, 2019).

The qualifier identifying the challenges for training scientists (see Box 1) has student *feedback* as its main contribution. Educational management needs to pay attention to these challenges, which occur above all in the teaching-learning process and concern the community and academic culture (Via *et al.*, 2014). Student *feedback*, therefore, when well articulated and thought out in the search for scientific evidence about the process, is an instrument for identifying reality (Via *et al.*, 2014).

In the area of public information, two qualifiers from the internal category (see Chart 1) are indicated by the authors: Maintaining information on scientific policies from governments and agencies and; maintaining a portfolio of activities that can be accessed by students in training. These two qualifiers relate to the need for information about educational policies and training activities, where educational management needs to be aware of the demands in these areas and provide information quickly and accurately to students.

The authors also make it clear that it is the role of educational management, during the process of training scientists, to maintain contact with other levels of education (see Chart 1). This qualifier of the internal category refers to the training of scientists beyond postgraduate studies, understanding that the process takes place at all levels of education and, therefore, must be present in the HEI's institutional policy (Voosen, 2023).

A specific qualifier concerns the work of post-doctoral students (see Box 1). Baltimor (2021) states that, in his experience of coordinating post-doctoral programs, he has achieved better results by giving students freedom and independence at this level of training. The postdoctoral internship is a partnership in which the person is free to do their research and work, in order to contribute to the program of training scientists based on their planning (Baltimor, 2021).

Connected to interdisciplinary and multidisciplinary issues, the formation of an inter-institutional faculty (see Chart 1), as a qualifier of the internal category, is pointed out by the authors as a diversification mechanism that influences research lines, the training of scientists and institutional dynamics.

Chardonnet (2015) explains that an inter-institutional faculty promotes partnership networks, the expansion and emergence of related lines of research, favors new research approaches, enables interdisciplinarity and/or multidisciplinarity and contributes to the training process by expanding institutional possibilities in the articulation of knowledge, infrastructure and political arrangements.

As for the lines of research, the authors present two distinct qualifiers. The first refers to the institutionalization of multidisciplinary and/or interdisciplinary projects to train scientists (see Chart 1), since institutionalization, through lines of research, reinforces the recognition of the need to build scientific knowledge in the frontier region of science.

The second qualifier is based on the need for dynamism between lines of research, in which students in training begin their process in basic lines and, as they specialize, enter specific lines of research linked to their research topics after completing a basic training cycle (Chardonnet, 2015).

The authors agree that educational management is responsible for the lines of research, which end up being addressed in an institutionalized way. This opens up the possibility of thinking about instruments and approaches for collegiate management of the lines of research, in order to offer greater dynamics, just as the authors refer to the curriculum, the lines of research can be the target of student *feedback*.

Our last qualifier in the internal category of "educational management" (see Chart 1) concerns the way in which scientists enter training programs (see Chart 1). Selection processes need to be designed based on the objectives defined by the scientist training program, considered as strategic factors for maintaining a network for building knowledge without, however, plastering these programs with the search for a unified student profile (Kupfer *et al.*, 2004).

Defining the objectives of the scientist training program is an integral part of the selection process, but it is not a sufficient condition for its existence (Kupfer *et al.*, 2004). Nor is it just a specific objective, but it brings together the institution's strategic objectives, whether short, medium or long term, as a strategy. In this way, the idea is that the selection process can reflect the needs of the program without standardizing an ideal type of student (Kupfer *et al.*, 2004).

The admission of people with different socio-cultural profiles contributes to the development of different ways of thinking. It is a qualifier of this selection process, which is based on socio-interactionism, reflecting on the necessary difference for the construction of scientific knowledge and the training of scientists. This cultural variability provided in the selection process is not, of course, a guarantee of a multiplicity of ideas; however, the opposite only presents us with the maintenance of the *status quo* (Kupfer *et al.*, 2004).

The inclusion of people with backgrounds in different areas contributes to the training of scientists by establishing a diversity of ways of thinking among students (Denton *et al.*, 2020). Scientist training programs need to be more inclusive, so that the diversity of people can be reflected in the reality investigated, based on the cultural interaction of different students in training contexts (Choudhury; Aggarwal, 2020).

According to the authors, the experiences demonstrate the need for diversity of backgrounds and cultural diversity as a factor that broadens the experience of research and training, in the interaction between people, with a view to providing interactions with different points of view between the people involved in the process of training scientists.

In this sense, social interactionism is revealed in the understanding that, in a teaching-learning process, there is a need for social interactions and cultural interactions, so that students in training interact, work cooperatively, solve problems and share their experiences.

INSTITUTIONAL POLICY, CAREER AND ACADEMIC COMMUNITY

The internal category "educational institution" (see Chart 1) concerns the institution's policy and its relationship with the process of training scientists. The main qualifier of this internal category concerns infrastructure (see Chart 1). The authors reinforce the need for laboratories, libraries, technologies, transportation for field research, living and study spaces, among others, as necessary support for the training of scientists.

As for technical support (see Chart 1), the authors demonstrate the importance of a technical-administrative team in constant dialog with scientists in training. In addition to support, administrative professionals have a professional history that can be linked to lines of research, exchanging experiences and knowledge with students in training (Hrynkow; Primack; Bridbord, 2003).

The academic events held by the institution (see Chart 1), with local awards, are presented as a qualifier with regard to the curriculum of students and their engagement in research processes. The authors state that these events and awards tend to have a positive impact on students' relationship with the construction of scientific knowledge and scientific communication (Via *et al.*, 2014).

Infrastructure, technical staff, events and awards are the qualifiers most cited by the authors, linked to direct actions carried out by the institution itself. The other qualifiers are specific to the authors' discussions and give us an idea of the daily life of the institution and how it can affect the process of training scientists.

Students in the process of training need to know the multiple possibilities of the institution (see Chart 1) is a qualifier of the internal category in the discussion about institutional communication. Knowing about the institution's daily routine involves communication and academic culture, publicizing courses, events, lectures; educational policies, public notices, scholarships; internship opportunities, fieldwork and inter-institutional partnerships, all of which are part of the institution's daily routine and require precise communication to make them accessible to students in the process of training.

The qualifier "the institutional environment reflects the process of training scientists" (see Chart 1) refers to institutionalized policy, related to culture and the academic community. Institutions whose mission is research can focus on training scientists and developing research centers, mobilizing their resources, policy and infrastructure in this direction.

Another obvious qualifier is that "training scientists reduces the material costs of research carried out at the institution" (see Box 1), in the sense that the more research experience there is, the less input and technology is wasted. This varies by area and has an optimum point of acquisition, through experience scientists in training reach this optimum point, but there is always a chance of error/waste to be mitigated.

As far as laboratory activities are concerned, the qualifier "training activities in laboratories should advocate student safety" (see Chart 1) refers to maintaining a constant "work safety" policy, with a view to guaranteeing safety in the research environment.

Two qualifiers in the internal category relate to institutional policies that make it possible for students to integrate and interact: "taking subjects in multiple courses and institutions" and "networking programs helps in the process of solving public problems" (see Chart 1).

The first concerns the construction of knowledge, which provides an opportunity to exchange experiences with education professionals, access to other fields of knowledge, interaction and integration between students with multiple perspectives that contributes to the training process (Mirali *et al.*, 2020).

The second is part of the discussion about evidence-based public policies, through the articulation of public institutions with training programs for scientists who work developing research that supports the decision-making of public agents. This articulation for the development of public policies requires institutional support, through a policy of inter-institutional collaboration, and contributes to the relationship with *praxis* for the training of scientists (Baiden; Hodgson; Binka, 2006).

The internal category "careers for scientists" (see Chart 1) covers discussions about training activities from the point of view of professional training to work in the job market, whether in academia, industry or other sectors.

The main qualifier relates to understanding the career of a scientist in training as a job (see Box 1), in defense of a salary for professionals in training or the guarantee of research grants. Bearing in mind that the training of scientists, as qualified in the category, requires long-term investment (see Box 1) and, often, full dedication (see Box 1) to the training process. The authors present this set of qualifiers as actions to guarantee an economically secure training process for students.

Scientific training grants have helped in the training process, but they are not enough to provide support for the formation of a career (D'onofrio; Gelfman, 2009), since scientists in training cannot be fully absorbed by academia itself and need to enter other job markets. This corroborates the idea that people are demotivated when it comes to a career as a scientist.

The authors understand that the process of training scientists must also qualify people for the job market (Önnerfors, 2007), discussing the training of scientists as a process of developing a career that goes beyond academia (Baltimor, 2021).

One of the experiences that point in the direction of academic training and the job market is the qualifier construction of a work and career plan in the process of training scientists (see Box 1).

This work plan involves the direct action of the scientist training program, keeping the training process in line with the world of work (Mueller *et al.*, 2015), integrating processes with professional practice (Smith *et al.*, 2021) and stimulating the development of skills that respond to regional needs (Flynn *et al.*, 2013).

In addition, in these experiences, the authors present the scientist training programs as spaces for reflection on the career of scientists, which goes beyond the construction of a plan, in which students reflect on their own career and the social relevance of scientific research.

These reflective qualifiers demonstrate the existence of spaces for socialization beyond the academic community and are constituted in the exchange of experiences with professionals who have graduated from courses, through lectures and training activities with professionals close to the job market (Lucas; Gora; Alonso, 2017).

Nonetheless, the level of professional training often ends up being an impediment to a professional career in peripheral capitalist countries, since the corresponding salaries are manipulated by the formation of an industrial reserve army (Mézáros, 2015), which ends up causing a brain drain and job insecurity. This only reinforces the contradictions of the production system.

The internal category "academic community" (see Chart 1) refers to the need to set up and maintain groups that collaborate in the process of training scientists through common scientific interests.

The category's main qualifier concerns the development and maintenance of an academic community (see Box 1), which provides support for programs to train scientists, taking into account their need from undergraduate level.

According to Canché (2016), this development and participation in the academic community has had an impact on the training process since graduation, and his data also shows that this relationship is correlated with better job prospects and future salaries. Networks, projects and research funding are part of these communities which, in addition to the training aspect (see Chart 1), develop from the relationships established by people and, as qualified in the category, need to be valued because they are an integral part of the dynamics of building scientific knowledge (Canché, 2016).

These communities are useful for valuing and critiquing students' scientific communications, in which people who have graduated from science training programs can contribute and guide students in the process of training (see Box 1) (Canché, 2016). These two qualifiers are linked to building relationships around an object of research in order to increase its educational potential.

Fitchett (2021) demonstrates, based on his report of an intervention in training processes for scientists, that communicating and discussing research results, whether verbally or in writing, has an impact on training. This impact can be realized in a pro-social environment, through academic communities, where graduates contribute their experiences through mentoring, which helps to broaden a professional vision (Lucas; Gora; Alonso, 2017).

Research groups (see Box 1) are qualified as part of this community, helping students to immerse themselves in research topics. Wilson et al. (2017), in their analysis of research groups, understand that they are part of the academic community and their main contribution is as study and discussion groups. Although limited in the experience analyzed by the author (Wilson *et al.*, 2017), these groups can contribute to training at theoretical levels.

Our final qualifier in the internal category concerns social networks as a space for building academic communities (see Chart 1). According to Gutierrez, Lazo and Espinosa (2015), the gains of building academic communities through social networks allow for internationalization processes, constant *feedback* and systematization of discussions, as long as the centrality of communication is directed at all the people who participate, becoming a learning community.

These academic communities bring together people's common interests and are spaces for integrating and building scientific knowledge. They create bonds between researchers, students, professionals and institutions in a space that values interpersonal relationships that are part of the life history and training of the people involved (Schwartzman, 1979; Lucas; Gora; Alonso, 2017).

CITIZEN SCIENCE AND SCIENCE COMMUNICATION

The internal category "citizen science" (see Chart 1) refers to social participation in the process of building scientific knowledge. Considered by the authors to be part of the training of scientists, citizen science requires training programs to raise social and political awareness about scientific activity. These qualifiers relate to accreditation and popular engagement, both in the training of scientists and in research processes.

Its main qualifier is the incorporation of society into the process of training scientists. Citizen science, as described by the authors, is a training process aimed at social contribution in which students carry out scientific training activities enabling other people to participate in the research process, contributing, for example, to data collection (Feldman; Ŝemaitė; Miller-Rushing, 2018).

Gallo and Waitt (2011) demonstrate the success of citizen science programs for monitoring invasive species in Texas, feeding databases that, compared to data collected by scientists and other groups, have similar accuracy. In this sense, the author (Gallo; Waitt, 2011) reinforces the social contributions, while highlighting the need for a training process for scientists and scientists in training, contributing not only to data collection, but also to the social accreditation of science by these communities.

The training process in citizen science is an ideal space for the first opportunities for teaching practice, with the supervision of teachers from the training program, as well as getting closer to society, it is possible to strengthen the academic community.

The internal category "science communication" (see Chart 1) brings together science popularization and dissemination activities carried out as part of scientist training programs. The aim of science communication is to make science more accessible and relevant to the population, promoting social engagement through the communication of science and technology, providing access to information through clear language by disseminating information (Albagli, 1996).

The main qualifier concerns science communication as an intellectual development activity (see Box 1) since, as trainees get involved, they can develop more sophisticated thinking and positive perspectives of their field by preparing content and interacting with a potential audience (Copple *et al.*, 2020).

The process of preparing content (content creation), in this sense, is an opportunity for students in training to reflect on their research, re-signify language and "translate" this scientific knowledge so that it becomes more accessible. However, as Albagli (1996) points out, care must be taken to rigorously review content creation in order to avoid imprecision, revisionism and reductionism.

The process of creating content is therefore a learning process qualified in the internal category (see Chart 1). This learning process can be institutionalized; the concerns of the connection between science communication and the curriculum studied by Dudley et al. (2021) show that the insertion of risk communication, communication theories and science communication provided better results in the training of scientists who become science communicators.

Obviously, the training process cannot be thought of only from the curricularization of components, but requires, as qualified by the authors, the development of skills and competences (see Chart 1) not only communicational, but a curriculum in action that is capable of supporting this production of content (Angelone, 2019).

This generation of scientists in training relates to and has knowledge of social networks, a space for interaction and dissemination of scientific communication, as qualified by the authors (Angelone, 2019). In this sense, the production of content as an opportunity for learning, with a view to science communication, reinforces the social role of science training programs and enables new relationships with the content being researched. By communicating this content, students in training have demonstrated new communicative possibilities for interaction between content-message-reception (Angelone, 2019; Dudley *et al.*, 2021).

The external effectiveness of science communication, in turn, helps us to understand the qualifier relating to the strengthening of academic communities (see Box 1). The research by Dudley *et al* (2021) shows that science communication increases the capacity for involvement in science education by engaging the possible public. If citizen science has expanded communities, then science communication as a mechanism for dissemination and engagement (Albagli, 1996) contributes to access to this science from a communicational perspective.

Social interaction and integration through science communication (see Chart 1) is qualified in the internal category, this phenomenon favors the social construction of science, expanding its accreditation processes and favoring public collaboration with scientists in training (Copple *et al.*, 2020).

This expanded form of scientific training, made possible by science communication, strengthens training processes through the internal effectiveness of science communication, in which students reflect on their skills during and with *feedback* from the public, but which also demonstrates external effectiveness, since scientific training is an aspect with a positive correlation to the results of science communication (Dudley *et al.*, 2021).

Science communication actions also strengthen the process of science communication in the training process, since in addition to the reflection and content creation process, communication skills are useful for science communication at academic events (Jensen, 2011).

One element of the criticism of science communication refers to the need for scientists in training to strengthen their links with science journalism (see Box 1). Journalists receive little or no scientific training and end up carrying out precarious science journalism activities, which can become speculative, reductionist and pseudoscientific (Kapoor, 2017).

In this sense, Holliman (2011) demonstrates that the participation of scientists in training in science journalism activities increases the credibility of science, the media and contributes in general to the training of scientists. In this sense, Metcalfe and Gascoigne (2005) understand that training scientists to create content contributes to science journalism and students, as it helps to develop a pro-social science media environment.

FINAL CONSIDERATIONS

Understanding pro-scientist training actions through an integrative literature review is a complex task, in which a series of experiences are systematized that converge, according to the authors, in activities with positive results in the process of training scientists.

These activities cut across different areas of knowledge, training experiences and institutions, which are expected characteristics of a multidisciplinary *corpus*. Even though the literature analyzed does not attempt to define its understanding of the training of scientists, these elements are present in the analysis of the categories which, in turn, are specified using qualifiers.

This analysis proposal made it possible to systematize these training actions in a more comprehensive way, not just subjecting them to a static section of the *corpus*, but composing a whole discussion that broadens the interpretation of each of the internal categories. The qualifiers proved to be efficient aspects for analyzing the main strategies for training scientists presented in the *corpus* analyzed.

The authors emphasize that interdisciplinary and/or multidisciplinary training contributes to the quality of the science developed by students, allowing contact with different areas of knowledge. A commonly cited experience is the training of translational scientists in the health area, which involves the relationship between basic and applied science, translating discoveries into practical actions quickly and efficiently.

These experiences reinforce the idea that the disciplinary training of scientists is not enough to deal with the complex issues of reality. Therefore, in the pedagogical practice of training scientists, we need to reflect on an educational policy that promotes interdisciplinary and/or multidisciplinary training.

The question of the dominance of bibliometrics and scientometrics as methods of information science is discussed throughout. These methods help students to understand the dynamics of scientific publishing and academic culture, providing support in making decisions about their own scientific communications.

The development of a methodological repertoire by students, in a way that allows them to understand the internal and external dynamics of the object of research, helps to strengthen decision-making on the construction of scientific knowledge.

International cooperation, through technological exchange and transfer, is a key element of training activities. Research programs facilitate the exchange of experiences between countries, developing institutional ties and promoting technical-scientific cooperation.

Short-term training courses focused on specific elements, such as theories and research techniques, are highlighted as formative actions aimed at meeting students' needs. Technical training, focused on digital technologies, helps students to operate and apply technical knowledge.

Research ethics is considered a formative element in these activities, recognizing that scientists must not only have technical and scientific mastery, but also an approach that promotes the well-being of the human species in their research processes.

Scientific governance is an important instrument that should be considered in scientist training programs because it fosters citizen science, broadens the accreditation of science and democratizes the process of training scientists.

Teaching activity must involve continuous training, with the discovery, organization, revision, deconstruction and reconstruction of theories in a reflective and practical way. Reflection on research agendas is also important, considering the current state of the field, the research questions and the approaches used. Reflection on the mentoring process and the contribution to student publications are also relevant aspects of teaching.

The main aspect of educational management is seeking *feedback* from students on the training process, allowing educational management to revise the curriculum in line with these contributions. Discussing the curriculum on the basis of practices, in a participatory and critical way, allows the institution to be reoriented and to reflect on the process of training scientists.

Promoting an inter-institutional and diverse teaching staff is highlighted as a mechanism that influences research lines, the training of scientists and institutional dynamics.

The selection processes must reflect the objectives of the scientist training program, taking into account the diversity of socio-cultural profiles and academic backgrounds in order to enrich interaction and the construction of knowledge. The inclusion of people from different areas contributes to diversity of thought and cultural interaction, enriching the research and training experience.

The HEI's infrastructure is highlighted as a key qualifier, including laboratories, libraries, technology and study spaces. The presence of a technical-administrative team is highlighted, as their interaction with students in training contributes to the exchange of experiences.

The networking of programs is also highlighted, especially when it comes to contributing to the resolution of public problems and the development of evidence-based policies.

The teaching career is approached as professional training and for the job market, including academia, industry and other sectors. There is a need to recognize the career of scientists in training as a job, advocating salaries and/or research grants for professionals.

When it comes to the academic community, pro-training actions highlight the importance of forming and maintaining collaborative groups that support the process of training scientists by sharing common scientific interests.

There is a need to develop and sustain an academic community that supports the training programs for scientists, starting from the undergraduate level. Studies show that involvement and participation in this community has an impact on the training process, correlating with better job opportunities and future salaries.

Citizen science is based on social participation in the process of building scientific knowledge, and is considered an essential part of the training of scientists, requiring training programs to raise social and political awareness of scientific practice.

Science communication, in turn, contributes to the training of scientists through activities that cover the popularization and dissemination of science carried out in science training programs.

Science communication is seen as an intellectual activity that allows students in training to develop more sophisticated thinking and positive perspectives in their fields, by preparing content and interacting with the public. However, care must be taken when creating content, avoiding inaccuracies and reductionism. Training scientists in content creation also benefits science journalism and contributes to the development of a pro-social media environment.

Summarizing the main findings of the research, we considered, for future studies, the relationship explored by the authors in the category "methodological training" (see Chart 1), with regard to aspects of the training of scientists linked to the domains of methods, techniques and research design/delineation and the gap pointed out by the authors that relates data science as an important field of study for scientific publication. This choice was made precisely because of the presence of category (f), which is also in line with the practices and requirements of scientific publication in postgraduate programs and has an impact on the lives of scientists in training.

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Author 1 - Data collection, data analysis and writing the text.
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Author 3 - Project coordinator, active participation in data collection, data analysis and revision of the final writing.

DECLARATION OF CONFLICT OF INTEREST

The authors declare that there is no conflict of interest with this article.