education sciences

MDPI

Article

Mapping Science Communication in Higher Education in Portugal: A Systematic Evidence Analysis of PhD and Master's Programs

Cecília Guerra [1,*], António Moreira [2], Pedro Pombo [3], Cecília Galvão [4], Cláudia Faria [5], António Granado [6], Ana Sanchez [7], João Carlos Paiva [8], Paulo Simeão Carvalho [9] and Elsa Costa e Silva [10]

1 Centro de Investigação em Didática e Tecnologia na Formação de Formadores (CIDTFF), Unidade de Ensino das Ciências, Faculdade de Ciências, Universidade do Porto, 4169-007 Porto, Portugal
2 Departamento de Educação e Psicologia, Centro de Investigação em Didática e Tecnologia na Formação de Formadores (CIDTFF), Universidade de Aveiro, 3810-193 Aveiro, Portugal; moreira@ua.pt
3 Fábrica Centro de Ciência Viva, Universidade de Aveiro, 3810-164 Aveiro, Portugal; ppombo@ua.pt
4 Instituto de Educação, Universidade de Lisboa, 1649-013 Lisboa, Portugal
5 Research and Development Unit in Education and Training (UIDEF), Instituto de Educação, Universidade de Lisboa, 1649-013 Lisboa, Portugal; cbfaria@ie.ulisboa.pt
6 ICNOVA—Instituto de Comunicação da Nova, Universidade Nova de Lisboa, 1069-061 Lisboa, Portugal; agranado@fcsh.unl.pt
7 Instituto de Tecnologia Química e Biológica António Xavier, Universidade Nova de Lisboa, 2780-167 Oeiras, Portugal; asanchez@itqb.unl.pt
8 Unidade de Ensino das Ciências, Faculdade de Ciências, Institute of Molecular Sciences (IMS), Centro de Investigação em Química da Universidade do Porto (CIQUP), Universidade do Porto, 4169-007 Porto, Portugal; jcpaiva@fc.up.pt
9 Unidade de Ensino das Ciências, Faculdade de Ciências, Instituto de Física dos Materiais Avançados, Nanotecnologia e Fotónica da Universidade do Porto (IFIMUP), Universidade do Porto, 4169-007 Porto, Portugal; psimeao@fc.up.pt
10 Centro de Estudos de Comunicação e Sociedade, Universidade do Minho, 4710-057 Braga, Portugal; elsa.silva@ics.uminho.pt
* Correspondence: cguerra@fc.up.pt

Abstract: Science communication training plays a crucial role in enabling scientists to effectively connect with the public, emphasizing essential skills such as building trust in scientific and technological advancements. Despite significant progress, some studies show a notable deficiency in higher education (HE) institutional structures and mechanisms dedicated to science communication training, addressing a diverse audience including researchers, teachers, and science monitors. This study delves into the key characteristics of current science communication postgraduate training programs within the HE landscape of Portugal. Our analysis is based on a comprehensive examination of the curricula of five science communication doctoral programs offered by four public universities in Portugal. The research involves a meticulous review of course documents and insights gathered from five directors through a detailed questionnaire. The primary objectives of this research are to discern the specific goals pursued by each course, uncover the content and development of competencies within their curricula, and explore the market opportunities envisioned by each offering. The results underscore that these programs equip students with the necessary competencies to effectively address challenges in science communication, notably enhancing public understanding of science. Significant findings suggest that Portugal's current higher education scenario predominantly emphasizes cultivating postgraduate training activities in authentic settings, fostering collaborative partnerships with society. This article is a foundational resource for further exploration into the discipline-specific applications of science communication, aiming to elevate academic engagement with society.

Keywords: professional development and training in science communication; scholarly communication; science education

check for updates

Citation: Guerra, C.; Moreira, A.; Pombo, P.; Galvão, C.; Faria, C.; Granado, A.; Sanchez, A.; Paiva, J.C.; Carvalho, P.S.; Costa e Silva, E. Mapping Science Communication in Higher Education in Portugal: A Systematic Evidence Analysis of PhD and Master's Programs. *Educ. Sci.* **2024**, *14*, 586. https://doi.org/10.3390/educsci14060586

Academic Editors: Dorothe Kienhues and Han Reichgelt

Received: 28 February 2024
Revised: 6 May 2024
Accepted: 21 May 2024
Published: 29 May 2024

1. Introduction

Science communication is a paramount social responsibility for scientists, serving as a prerequisite for fostering comprehensive, engaged, critical, and well-informed citizenship. This commitment is indispensable for empowering citizens to actively participate in and contribute to the discourse surrounding scientific advancements. Davies [1] delineates the multifaceted roles of science communication within society, categorizing them into five overarching domains:

1. Accountability: Scientists are responsible for communicating their work transparently, mainly when funded by public resources. This transparency is imperative for earning and maintaining public trust.
2. Pragmatic or Instrumental: Science communication should yield valuable knowledge to specific societal actors, such as policymakers. Its utility lies in providing information that is directly applicable to addressing societal challenges.
3. Enhancing Democracy: As a crucial input into public debates, science communication facilitates discussions about societal values and priorities. It is pivotal in shaping how these considerations influence scientific research and contribute to democratic deliberations.
4. Role in Society (Democracy Overlapping): Science communication fosters shared understandings of scientific issues with potential political, social, and cultural implications. Doing so actively contributes to a collective comprehension of the broader societal impact of scientific advancements.
5. Promotional Purposes: Science communication extends beyond the dissemination of knowledge, encompassing promotional aspects. This includes individual and institutional marketing and branding endeavors, such as universities promoting their research and the broader promotion of science.

In essence, the multifaceted nature of science communication underscores its significance as a channel for responsible scientific engagement with the public, contributing to societal well-being and fostering a culture of informed citizenship.

The communication of science and technology (S&T) to the public unfolds across diverse arenas, including science journalism, science centers, and museums, non-formal and informal science education, science outreach, and public information for research-focused organizations [2].

Despite this rich landscape, the existing body of science communication research often leans towards either highlighting specific communication contexts, such as crafting popular articles or participating in television interviews, or delving into the intricacies of educational contexts, such as designing specific training programs. Educators, including those in higher education (HE), play a pivotal role in fostering the empowerment of scientists to engage with citizens effectively. It is crucial to discern how academics, encompassing researchers and teachers, prepare their students at the master's and doctoral levels to mobilize S&T knowledge within society effectively.

Recognizing the significance of this interaction, there is a pressing need to invest in capacity building within HE institutions for effective science communication. In response to this imperative, public universities in Portugal have proactively initiated and integrated science communication postgraduate training programs. These programs aim to equip students with the skills and knowledge essential for communicating scientific concepts and establishing meaningful connections with the broader public.

With this goal in mind, the present study aims to systematically chart the landscape of postgraduate programs (including master's and doctoral degrees) within Portuguese higher education (PHE). Despite the prevailing trend towards increased convergence, notably propelled by the Bologna implementation process, Portuguese universities maintain a distinctive emphasis on conceptual depth and research-oriented pursuits [3]. Offering degrees across bachelor's (first cycle of studies), master's (second cycle of studies), and doctoral levels (third cycle of studies), these institutions have experienced a substantial surge in student enrollment. National statistics reveal a noteworthy escalation, with the number of higher education students in Portugal skyrocketing from 30,000 in the 1960s to

approximately 400,000 in 2020 [4,5], surpassing the enrollment proportions observed in many other European countries [6].

In response to this remarkable increase, the Portuguese Government implemented a numerus clausus system in 1977, strategically limiting the number of available university places each academic year. In the 2019/2020 academic year, a collective total of 384,391 students were actively enrolled across the three study cycles [4]. However, the allocation of workload may vary based on the responsibilities of academic staff that explicitly incorporate science communication in their curricula.

This article undertakes an analysis of the curriculum (comprising learning goals articulated across the entire educational experience) and the syllabus (outlining topics to be covered in a course) of postgraduate training programs in science communication in Portugal. Table 1 presents six research questions and six overarching aims to guide this examination.

Table 1. Research questions and aims of the study.

	Questions		Aims
1.	What are the postgraduate programs offered in science communication in Portugal?	1.	To identify and describe the postgraduation programs offered in science communication in Portugal.
2.	What are the Portuguese postgraduate programs' primary teaching and learning goals?	2.	To identify Portuguese postgraduate teaching and learning programs' goals.
3.	What is the primary identity of the postgraduate programs offered in science communication in Portugal?	3.	To characterize the identity of the postgraduate programs offered in science communication in Portugal.
4.	Who are the participants of the Portuguese postgraduate programs?	4.	To identify the Portuguese students' and teachers' postgraduate program profiles
5.	What is the level of partnerships/connection of the Portuguese postgraduate programs to society?	5.	To identify partnerships/connections established between the Portuguese postgraduate programs and society.
6.	What are the academic outputs derived from Portuguese postgraduation programs?	6.	To identify the Portuguese postgraduate programs' academic outputs.

These six questions hold significant importance as they enable the characterization of existing postgraduate programs in science communication training in Portugal. They also provide insights into the key characteristics of learning goals (curriculum) and learning objectives (syllabus) within each program.

This study aims to comprehensively characterize postgraduate training in science communication conducted in Portuguese public universities. However, it is essential to emphasize that each of the analyzed programs/cases has its own distinct identity, shaped by the institution's characteristics, the region where it is located, and the history built over time.

2. Rationale

Several authors [7–9] delineate that specific training programs cater more towards undergraduate or graduate students in science, technology, engineering, arts, and mathematics (STEAM). In contrast, others target professionals engaged in diverse contexts, such as science museums. According to Baram-Tsabari and Lewenstein [2], the nature of these programs varies widely. Some are brief 'one-off' sessions lasting an hour or two on a single day, while others extend to day-long or week-long workshops, repeated multiple times annually. Additionally, comprehensive degree programs are available, spanning both graduate and postgraduate levels. Participants may engage in a single event or opt for repeated opportunities to enhance their science communication skills. It is noteworthy

that while specific science communication training programs focus specifically on honing particular communication skills, others aim to educate participants on broader concepts encompassing education, communication, and the intricate interplay between science and society [10–17].

However, there remains a need for further development in the realm of science communication training. Indeed, certain studies indicate a persistent deficiency in higher education (HE) institutional structures and mechanisms dedicated to training in science communication, catering to a diverse array of professional profiles, including scientists, teachers, and science monitors. Moreover, to date, more research has yet to delve into the underlying attitudes, perceptions, and intentions of participants engaging in science communication training programs [18].

Attempting to cover all facets of science communication within a single curriculum proves challenging and often exceeds the scope of most training programs [2]. The structure of science communication programs is intricate, given the diverse contributions from various disciplines, each providing unique ideas, content, and complementary skills to the field [15]. For instance, one conceptual approach may draw from communication research, often intertwined with designing communication campaigns that center on knowledge, attitudes, skills, and behavior change.

An alternative approach involves aligning goals with specific practical dimensions, encompassing various aspects such as the types of activities being trained for (e.g., museums, media), the goals of different programs (conceptual knowledge, specific skills), the skills/competencies/domains of knowledge being taught (principles of learning, media production techniques), the target audiences (children, adults), and the science communicators being trained (scientists engaged in outreach, environmental writers) [2].

Establishing a clear conceptual foundation grounded in educational research is essential to elucidating the relationships, complementarities, and tensions inherent in diverse science communication contexts. By delineating conceptually based learning goals, Baram-Tsabari and Lewenstein [2] aim to contribute to a more robust conceptualization of the field of science communication training. In this context, drawing inspiration from Bell, Lewenstein, Shouse, and Feder [19], Baram-Tsabari and Lewenstein [2] have formulated a set of science communication learning goals adapted from the six strands of science learning (refer to Table 2).

Table 2. Science communication strand and learning goal (adapted from Baram-Tsabari and Lewenstein [2]).

Goal Strand	Learning Goals
Affective goal	Experiences excitement, interest, and motivation about science communication activities and develops attitudes supportive of effective science communication.
Content goal	Comes to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science communication.
Methods goal	Uses science communication methods, including written, oral, and visual communication skills and tools, to foster fruitful dialogues with diverse audiences.
Reflective goal	They can reflect on science and science communication's role within society, processes, concepts, and institutions of science communication, and their own method of learning about and doing science communication.
Participatory goal	Participates in scientific communication activities in authentic settings, creating written, oral, and visual science messages suitable for various non-technical audiences and engaging in fruitful dialogues with those audiences.
Identity goal	Thinks about herself or himself as a science communicator and develops an identity as someone who can contribute to science communication.

Compiling the learning goals for science communication into a single conceptually driven list serves the purpose of pinpointing strengths in existing science communication training programs and areas that necessitate further attention. As noted by Baram-Tsabari and Lewenstein [2], specific lists of learning goals overlook distinctions between brief half-day workshops and more extensive semester-long programs, such as those integrated into postgraduate programs. The authors advocate for identifying a comprehensive set of learning goals that draw from the full spectrum of disciplines contributing to the public communication of science and technology. This inclusive approach spans communication, journalism, arts and media production, education, public relations, marketing, and science and technology studies. To enhance these objectives, it becomes imperative to establish benchmarks that define effective science communication practices. Additionally, tools need to be developed to assess and evaluate specific training programs, acknowledging the inherent complexity of such endeavors.

In this context, the authors mentioned above recommend that future research on science communication should strive to (1) establish connections between these learning goals and the overarching objective of achieving effective science communication, (2) discern which learning goals are suitable for specific audiences, and (3) identify the profiles of students in science communication programs, such as those explicitly pursuing careers in science communication or those aiming to integrate science communication within a broader context, as seen in students enrolled in science-and-society programs, among others.

3. Methods

A case study plan using an interpretative and qualitative research method was adopted in this study [20–22]. As defined by [22], case studies utilize data from a specific real context to explain, explore, or describe current phenomena. Case studies aim to uncover hidden phenomena, emphasizing the context, focusing on individuals, groups, organizations, or communities, and interpreting it from various perspectives to allow analytical generalizations [20–22].

Data are collected empirically [23,24] in two distinct phases: (1) an analysis of the five science communication programs available in four Portuguese public universities, and (2) a questionnaire (open-ended questions) administered to the five directors of the five programs. To this end, we propose several research aims and data collection procedures, as presented in Table 3.

Table 3. Articulation between the research aims and data collection of the study.

	Aims	Data Collection
1.	To identify and describe the postgraduation programs offered in science communication in Portugal.	Documents of five programs
2.	To identify Portuguese postgraduate teaching and learning programs' goals.	
3.	To characterize the identity of the postgraduate programs offered in science communication in Portugal.	Directors' opinions were collected through a questionnaire.
4.	To identify the Portuguese students' and teachers' postgraduate program profiles.	
5.	To identify partnerships/connections established between the Portuguese postgraduate programs and society.	
6.	To identify the Portuguese postgraduate programs' academic outputs.	

The first phase involved collecting documents from five science communication programs available at four Portuguese public universities. A search on the "Agência de Avaliação e Acreditação do Ensino Superior (A3ES)" website (https://www.a3es.pt/en, accessed on 1 September 2023) using search strings such as "Comunicação de Ciência", "Divulgação de Ciências", AND "Educação Científica" identified four HE institutions offering programs in this domain: four master's programs and one PhD. Notably, one master's program offered by a university was discontinued in 2013 and consequently excluded from the study.

A content analysis technique [20] was employed to scrutinize the curricular units (CU) within five programs, with a specific focus on the science communication strand and learning goals pursued by each of them, their contents and competencies development, and the market opportunities envisioned by each offering. Our analysis followed a content analysis technique [20] due to its inherent nature: we purposefully conducted a meticulous and comprehensive examination of our reading, aiming for a broad understanding of what could be considered a learning goal in science communication training; our initial exploration involved programs that we were familiar with, and we extended our search by utilizing the reference lists of master's degree dissertations and PhD theses in RCAAP—Repositórios Científicos de Acesso Aberto de Portugal (https://www.rcaap.pt; accessed on 1 September 2023), produced in those training programs.

The written documents collected from five postgraduate programs served as the individual source of information for the content analysis, which facilitated research objectivity. One researcher (the co-author of this paper) analyzed each written document. The target of the researcher's analyses took various forms, including essential pedagogical elements of the programs (e.g., contents, goals, and strategies). The researcher also conducted literature searches using various terms related to science communication training and assigned meaningful pieces of text to previously defined categories (ex. contents, goals, and strategies).

Aligned with the learning goals structure proposed by Baram-Tsabari and Lewenstein [2], the researcher initiated the process by consolidating statements present in the curriculum of postgraduate programs (e.g., "Cultura Científica e Divulgação das Ciências" from the Universidade de Lisboa). Through multiple iterations, the researcher systematically organized the statements into the six-strand structure proposed by Baram-Tsabari and Lewenstein [2], consolidating similar statements and refining them into a consistent 'learning goal' format. Finally, the researcher compiled a list that was based on a qualitative analysis of five training programs, comprising one PhD course and four master's degree programs.

This analysis was discussed and reviewed by other researchers on this team to assure greater reliability. To promote research objectivity of the content analysis of documents, each director of the postgraduation programs analyzed also provided ad hoc verification of the researcher's systematization.

The first phase served as a baseline, reflecting on the theory and practice of the five programs, rather than an evaluation of a program. This ensured robust interpretative analysis and conclusions [24].

In the second phase of research, data were collected through the administration of an individual questionnaire to the five directors of the previously analyzed programs [22]. Quantitative and qualitative issues (categories and indicators) were collected through the questionnaire. Regarding quantitative data, each director provided information covering the period from the academic year 2018/2019 to 2022/2023, except for the cases of the master's in science teaching and dissemination at the University of Porto and the master's degree in science communication at the University of Minho. In these instances, the data pertained to the academic year 2019/2020 to 2022/2023.

The questionnaire also allowed for the collection of reflections provided by the five directors of the analyzed programs. For this purpose, the following three open-ended questions were posed:

(1) What were the positive aspects and challenges or difficulties (e.g., professional outlets) associated with the programs?
(2) According to the five directors, what sets the postgraduate offerings apart from others on the national and international stages?
(3) What were the primary prospects for postgraduate programs in national and/or international contexts?

Ethical review and approval were waived for this study, as data protection was ensured by adhering to institutional protocols in each higher education institution, including established data collection procedures. Figure 1 presents the five cases analyzed and the categories and indicators collected through the close-ended questions of the individual questionnaire.

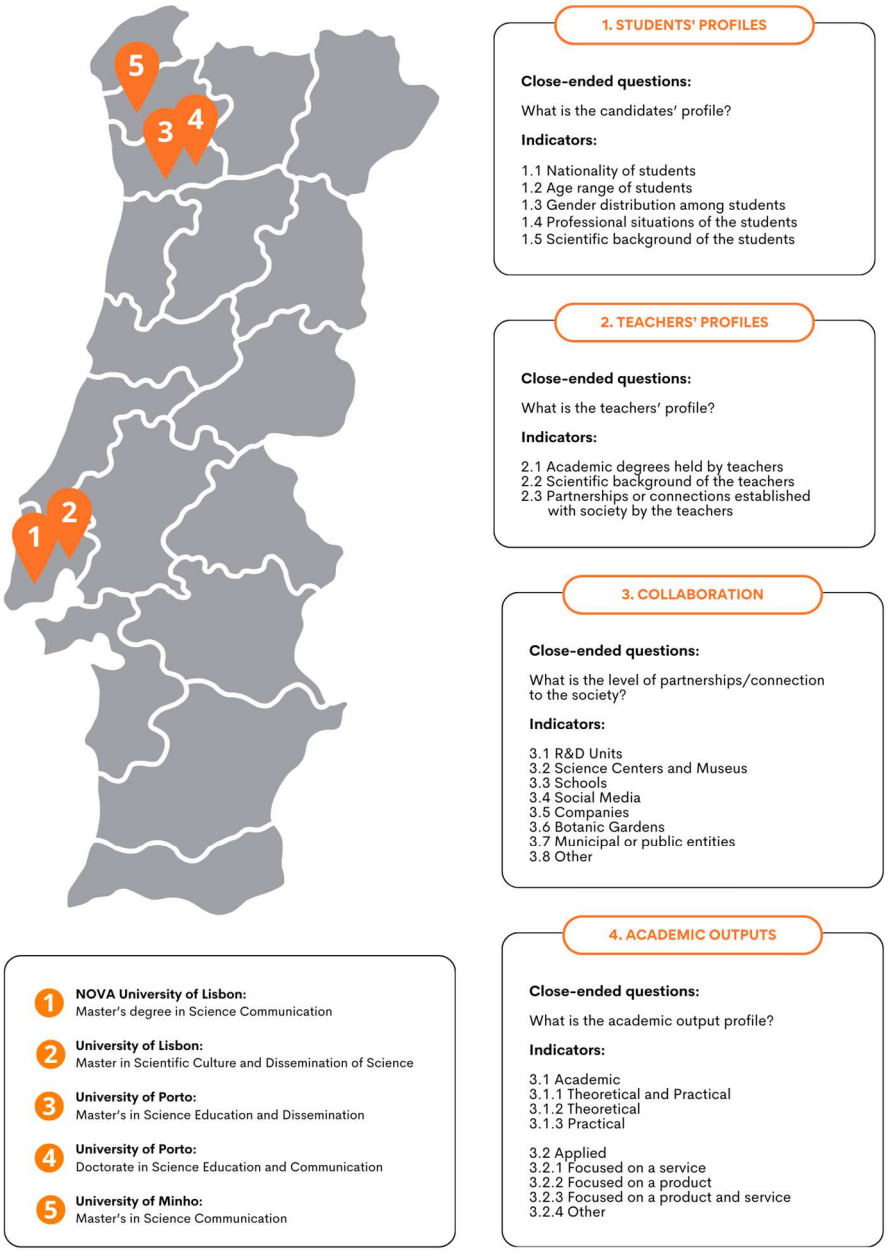

Figure 1. Cases were analyzed, and the categories and indicators were collected through the close questions of the individual questionnaire.

A content analysis technique [20] using Excel software 2021 (Microsoft 365) was applied to the data collected (open-ended questions). The analysis of the perceptions of five directors helped to explore specific actions and principles applied in each program. Qualitative analysis involved specifying the characteristics of a participant's statement (five directors), coding them, and using descriptive techniques to analyze the data. Through an iterative process of reading and re-reading data [22], we assigned meaningful pieces of text to previously defined categories (ex. contents, goals, and strategies). In effect, the coded categories were treated as variables.

The content analysis procedure was similar to the first research phase, the distinction being whether the data were used to attempt to interpret meanings or focus on identifying dominant tendencies of pedagogical actions implemented in programs. Indicators of analysis have emerged from the authors' conceptualizations of science communication training [2] and from the content analysis process [20]. The results are presented in the following section.

4. Results

Section 4.1 provides a holistic panorama encompassing the content analysis of the documents of five postgraduation programs based on website information from each institution. Section 4.2 presents insights shared by the five directors of the analyzed programs, derived from content analysis of open-ended questionnaire responses [23,24], revealing the distinctive features and identity that set the postgraduate offerings apart within the national landscape. Section 4.3 presents an overview of postgraduate training in science communication across Portugal, derived from quantitative analysis of closed-ended questionnaire responses.

4.1. Presentation of the Postgraduate Programs

This section identifies and describes the programs offered in science communication in Portugal.

4.1.1. NOVA University of Lisbon: Master's Degree in Science Communication

The master's in science communication at NOVA University of Lisbon (codification: NUL_M) is a collaborative initiative between the Institute of Chemical and Biological Technology and the Faculty of Social Sciences and Humanities at NOVA University of Lisbon. Throughout the coursework phase of the master's program, students engage in discussions about the intricate relationship between science and society, exploring the responsibilities of scientists within this dynamic. The curriculum explores the evolution of the concept of science communication, providing comprehensive insights. It includes training in strategic communication and journalism tools, equipping students with practical skills. Moreover, students are exposed to real-world examples of successful communication projects, fostering a practical understanding of effective communication strategies. The active involvement of Portuguese scientists and experienced science communicators is noteworthy, complementing the contributions of the formal teaching staff responsible for various curricular units. For additional details, refer to the data available at https://www.fcsh.unl.pt/en/programs/science-communication-nova-fcsh-itqb-nova/ (accessed on 1 September 2023).

4.1.2. Lisbon University: Master in Scientific Culture and Dissemination of Science

The master's course "scientific culture and the dissemination of science" at Lisbon University (codification: UL_M) is a collaborative effort involving various schools within the University of Lisbon. This collaboration taps into the multidisciplinary knowledge generated across these schools. The participation of different schools and museums creates opportunities for synergies, enhancing the overall quality of this master's course. The primary goal of this program is to train professionals to develop strategies to promote scientific culture among citizens. Communication and dissemination perspectives are integrated

at various levels throughout the course, providing a comprehensive understanding. For more information, visit http://www.ie.ulisboa.pt/ensino/mestrados/cultura-cientifica-divulgacao-ciencias (accessed on 1 September 2023).

4.1.3. Porto University: Master's in Science Education and Dissemination

The University of Porto offers two postgraduate programs: the master's in science teaching and dissemination (UP_M) and the doctorate in science education and communication (codification: UP_PhD). These programs result from collaborative efforts involving faculty members from the Science Education Unit at the Faculty of Sciences and its thematic departments, covering areas such as mathematics, physics, astronomy, chemistry, biology, and geology. This diverse and experienced faculty ensures a robust and well-rounded range of opportunities for advanced training in science teaching and outreach through research. The close connection to research in the covered science fields ensures a productive and highly innovative approach to current science education and outreach research topics.

Specifically, the master's program in science teaching and dissemination (codification: UP_M) aims to enhance students' training in fundamental and contemporary science topics, strengthening science education within a lifelong learning perspective. It also focuses on developing analytical and critical reflection skills in science communication for diverse audiences and, through various means, aims to promote scientific culture. For more information, visit https://mestrados.fc.up.pt/mestrados/ensino-e-divulgacao-das-ciencias/ (accessed on 1 September 2023).

4.1.4. University of Porto: Doctorate in Science Education and Communication

The doctorate program in science education and communication (codification: UP_PhD) targets advanced training for science teachers and communicators, addressing education, communication, and public outreach issues. Importantly, it remains closely linked to specific scientific areas within the physical and natural sciences. Students are expected to acquire multidisciplinary and interdisciplinary skills related to teaching and popularizing mathematics, physics, astronomy, chemistry, biology, and/or geology. For more information, visit https://sigarra.up.pt/fcup/en/UNI_GERAL.UNIDADE_VIEW?pv_unidade=127 (accessed on 1 September 2023).

4.1.5. University of Minho: Master's in Science Communication

The master's degree in science communication at the University of Minho (codification: UM_M) is designed to provide high-quality training for individuals involved in promoting communication in institutions with a significant scientific focus, such as research centers, clinical facilities, museums, and science dissemination institutions. The program aims to enhance internal and external communication for these institutions across various platforms. Objectives include establishing international communication networks and equipping individuals with practical techniques to convey their work. The master's course also seeks to impart multidisciplinary knowledge to students, enabling them to conduct in-depth research in science communication. The program strives for excellence in scientific and technical training within national and international contexts. Furthermore, it actively collaborates with various regional and national institutions, fostering a continuous and close relationship between the academic environment and society. For further details, visit https://www.ics.uminho.pt/en/Ensino/Master-Degrees/_layouts/15/UMinho.PortaisUOEI.UI/Pages/CatalogoCursoDetail.aspx?itemId=4683&catId=14 (accessed on 1 September 2023).

4.1.6. Teaching and Learning Goals of the Postgraduation Programs

The initial phase entailed content analysis of documents, comprising the process of examining and interpreting data to extract meaning, gain understanding, and develop empirical knowledge [20,21]. Aligned with the learning goals structure proposed by Baram-Tsabari and Lewenstein [2], we initiated the process by consolidating statements

present in the curriculum of postgraduate programs (e.g., "Cultura Científica e Divulgação das Ciências" from the Universidade de Lisboa). These statements took various forms, including goals, objectives, and essential elements. We have compiled existing statements regarding goals and outcomes in science communication training. Additionally, where necessary, we have identified additional learning goals not previously listed but suggested by the conceptual framework. The learning goals identified in the analyzed programs are presented in Table 4.

Table 4. Science communication strand and learning goals were analyzed in the data collected (adapted from Baram-Tsabari and Lewenstein [2]).

Goal Strand	Learning Goals Description	Number of Identified References	Examples Extracted from Documents
Affective goal	Develops attitudes and experience of effective supportive science communication.	NUL_M (1 ref) UP_M (1 ref)	"To make future communication and education professionals more enthusiastic about science communication in its various forms" (NUL_M).
Content goal	Understands and applies concepts, strategies, and resources related to science communication.	UP_M (1 ref) UM_M (1 ref)	"... to train high-quality professionals to promote communication in institutions that have a scientific component in their activities (for example, research centers, clinical centers, museums, science communication institutions, among others)" (UM_M).
Methods goal	Produces written, oral, and visual communication resources and tools to foster dialogue with diverse audiences (society, schools, etc.).	UP_M (1 ref)	"Enhancing the development of science communication skills, training communicators to energize events and physical and virtual science communication spaces for various audiences" (UP_M)
Reflective goal	Reflects on the nature of science and science communication's role within society.	UL_M (1 ref) UP_M (1 ref) UM_M (2 ref)	"Reflect on the importance of conceptualizing and organizing scientific heritage in museums and science centers" (UL_M)
Participatory goal	Participates in science communication events to disseminate the learning outputs.	UL_M (1 ref) UM_M (3 ref) UP_PhD (1 ref)	"The training offered by the program ensures the acquisition of competencies that are important for the long-term building of a scientifically literate society, through actively improving the training on teaching at all levels, as well as teaching practices, and also towards expanding and strengthening the impact and quality of the role of museums and science outreach institutions" (UP_PhD).
Identity goal	She/He thinks about her- or himself as a science communicator and develops an identity as someone who can contribute to science communication.	All postgraduate programs contribute to this strand goal.	

These programs progressively emphasize strands, ascending from Affective to Identity. Table 4 represents the degree of emphasis identified in each program. In other words, all five programs have the same goal strand organization. The intervening strands serve as methodological steps connecting the Affective and Identity strands, focusing on aspects such as accessing content and methods, reflective practices, and active participation. Regarding the goal strand "Affective goal", one example identified in the content analysis of

the document of NUL_M was "To make future communication and education professionals more enthusiastic about science communication in its various forms".

Concerning the goal strand "Content goal", one example identified in the content analysis of the document of UM_M was "to train high-quality professionals to promote communication in institutions that have a scientific component in their activities (for example, research centers, clinical centers, museums, science communication institutions, among others)".

As to the goal strand "Methods goal", one example identified in the analysis of documents of UP_M was "Enhancing the development of science communication skills, training communicators to energize events and physical and virtual science communication spaces for various audiences".

Concerning the "Reflective goal" aspect, one example identified in the content analysis of the document of UL_M was "Reflect on the importance of conceptualizing and organizing scientific heritage in museums and science centers".

Concerning the goal strand "Participatory goal", one example identified in the content analysis of the document of UP_PhD was "The training offered by the program ensures the acquisition of competencies that are important for the long-term building of a scientifically literate society, through actively improving the training on teaching at all levels, as well as teaching practices, and also towards expanding and strengthening the impact and quality of the role of museums and science outreach institutions".

Finally, regarding the goal strand "Identity goal", all postgraduation programs contribute to this strand goal.

These results reveal the comprehensive coverage of all learning goals across the training programs, encompassing Participatory, Affective, Reflective, Identity, Content, and Methods strands. The second research aim (to identify Portuguese postgraduate teaching and learning programs' goals) seeks to understand the incorporation of critical theoretical principles from strategic science communication into curricula. Specifically, it aims (i) to ascertain the extent to which programs assist students in fostering active listening, embracing a dialogic approach, and prioritizing audience-centeredness, as emphasized in the excellence theory of public relations [25]; (ii) to examine whether programs prioritize strategic thinking in communication over technical communication abilities [2] and whether they emphasize establishing behavioral goals and communication objectives before selecting specific communication strategies [7].

4.2. Directors Reflections on Science Communication Training in Portuguese Postgraduation Programs

In this section, we will showcase insights shared by the five directors of the analyzed programs. These reflections include positive aspects, challenges, or difficulties encountered, such as professional outlets. Additionally, we will explore the distinctive features that, according to the coordinators, set the postgraduate offerings apart within the national landscape. Moreover, we will explore the expected prospects for the postgraduate programs on a national and international scale, all based on the individual answers to the open-ended questions applied to the five directors. The following sections are a synthesis of those same answers.

4.2.1. Case 1: NOVA University of Lisbon: Master's Degree in Science Communication

The master's program in science communication started in 2011 as a joint venture between two units of the NOVA University of Lisbon (codification: NUL_M): the Institute of Chemical and Biological Technology and the School of Social Sciences and Humanities. The program emerged as a response to the increasing need felt by those who, having obtained a degree in natural sciences, engineering, communication, or education, were required to deal with science communication daily.

From the beginning, the main objective of this course was to provide the students with the theoretical perception and practical skills to overcome the challenges of their

professional practice. The groups targeted by this master course include professionals working in media, science institutions, strategic communication offices, schools, and science centers who want to strengthen their knowledge and expertise in science communication.

Over the past twelve years, the NOVA master's has attracted over 240 students from diverse educational and professional backgrounds, ranging from recent bachelors to retired professors. While natural and exact sciences figure strongly, the diversity of experiences and perspectives in class triggers animated discussions and dramatically enriches the teaching and learning experience for students and teachers.

In the first two semesters, the master's course is organized into six in-depth programs. Two aim to reflect on the nature of science and its relationship with society. Three focus on more specific domains of science communication, namely science journalism, formal and informal science education, and science communication in research institutions. The sixth course presents students with various practices and techniques that may be explored when communicating science.

In the third and final semester, students opt for writing a dissertation, designing a science communication object, or experimenting with science communication at an organization of their choice. In all cases, students produce a written document and discuss their work with external experts.

Both science and communication have evolved in the last decade, and today, science communication differs from 12 years ago. We try to reflect these changes in all six master programs while encouraging students to explore and reflect on the challenges of science communication in the 2020s. The profile of students has also been evolving. While many were looking for (and succeeded in) a career change in the past, more are now looking into science communication for their first career.

In twelve years, NOVA is proud to have populated the country with alumni, primarily in research and academic institutions, but also in science centers, science communication companies, and science journalism. The recent creation (2022) of specialization in science communication in the PhD course in communication sciences gives NOVA a new perspective on the evolution and strengthening of this area at NOVA University and in Portugal.

4.2.2. Case 2: Lisbon University: Master in Scientific Culture and Dissemination of Science

In the case of the master's course on scientific culture and science dissemination at the University of Lisbon (codification: UL_M), the main driver is the idea that knowing the processes of scientific knowledge production, as well as several areas where significant developments are currently taking place, will promote a deep understanding of the implications of communicating science to different audiences through various channels. The course brings together a truly interdisciplinary faculty committed to a shared responsibility in coordinating and teaching each curricular unit and thesis supervision, which creates an opportunity to generate synergies from different areas of knowledge, from the social sciences and humanities to the natural sciences and engineering. This gives the opportunity to learn in various areas of expertise, which is helpful for any professional in the field of public dissemination of science.

To respond to the central idea of this course, besides other curricular units, students are involved in four practical laboratories related to "health sciences", "engineering and technology sciences", "earth, sea, and space sciences", and "social sciences and humanities", in which they encounter research projects, current scientific topics, research priorities and policy, communication, management, and ethics in all these areas. These laboratories are curricular units that are much appreciated by the students due to their practical nature, the contact with the several schools (faculties and institutes of the University of Lisbon) involved, and the work of scientists and science communicators from very different areas.

As main strengths, we consider the following: the current theme and its great relevance for the cohesion of democratic societies through the possibility of discussion and the construction of scientific arguments against disinformation; EC is integrated in the University of Lisbon, offering the quality and diversity of an experienced faculty, members

of recognized research centers, connections to civil society and the business sector, and high internationalization and multidisciplinary knowledge produced in the faculties and institutes involved, identified by students as being very useful for their training; collaboration between several schools represents an opportunity to create synergies in different areas of knowledge, giving this master's degree undeniable quality potential; high-quality infrastructures in the various institutions involved; and the possibility for master's students to develop their dissertation/project or carry out an internship in different schools, communication offices and museums, and science centers.

As weaknesses, we emphasize the irregular number of applicants that may compromise the functioning of the course and the insufficient advertisement of the course among specific groups, namely professionals working in science centers and museums and science managers.

The students who have been attending the master's degree program have diversified their areas of training. For example, in 2021/22, candidates had backgrounds in biology, teaching physics and chemistry, forest engineering, nutrition, psychology, law, pharmacy, sociology, literature, design, journalism, and history. Most of them have jobs in science dissemination areas, such as science centers and science museums. Still, there are also some teachers in primary and secondary education and higher education, which is an indicator of rich interaction and learning.

4.2.3. Case 3: Porto University: Master's in Science Education and Dissemination

This course originated from the teaching master's programs in specific areas of exact sciences at the Faculty of Sciences of the University of Porto (FCUP) (codification: UP_M). It took its current form in 2019, becoming the only master's degree in Portugal that combines advanced training in science education and science communication. The course spans four semesters over two years.

In the first year, students undergo training in fundamental aspects of epistemology, the history of ideas in science, research methodologies in education and communication, and science dissemination practices. This includes using multimedia, robotics, and programming as educational tools provided by FCUP professors. Students present creative works on teaching or dissemination practices, ready for use in scientific events. Alongside this training, students can choose additional units to align with specific interests, such as design thinking, museum resources, multimedia platforms, and communication techniques.

Classes in the first year are concentrated on two afternoons a week, while the second year is dedicated to writing a dissertation, either academic or applied research in science education or communication.

The course offers diverse professional opportunities, combining advanced training for intervention in teaching practices and opportunities in science communication spaces such as museums, science centers, and communication offices. The target audience comprises graduates in exact and natural sciences, engineering, and technology, mainly Portuguese (51%), Brazilian (27%), and from other Portuguese-speaking countries (2%).

The course attracts a balanced number of men and women, with an average age of around 30. Approximately two-thirds of the students have prior teaching or science dissemination experience. The course has delivered 83% of dissertations in the communication component and 17% in the education component over four editions, indicating a high degree of internationalization and a demand for science communication training. The course is expected to continue attracting graduates interested in science communication while achieving a gradual balance between the two components, responding to the demand for advanced training by exact sciences teachers.

4.2.4. Case 4: University of Porto: Doctorate in Science Education and Communication

The doctoral degree is born and developed in a centenary faculty with an excellent scientific tradition and an intense connection to teacher education (codification: UP_PhD). For about twenty years, FCUP (Faculty of Sciences of the University of Porto, Porto, Portugal)

has been enhancing its staff with PhDs in science education, strengthening the area. In this way, the long, intense, and qualified scientific strength has been allied with the specialization in teaching and dissemination of science, including investigative and methodological aspects. Nowadays, the doctoral degree has well-defined standardized frameworks of typical research in science education that are developed nationally and internationally.

In addition to the above implicit strength, linked to the complicity of the exact sciences themselves (chemistry, physics, biology, geology, astronomy, and mathematics) with the respective research in education and dissemination, the course is located in a nationally and internationally favorable geographical area, connected to a renowned university, such as the University of Porto. Many of the activities developed at the university are enhanced downstream and upstream with this PhD. Particular emphasis is on works related to the following: 1—research centers of excellence in the areas of earth and life sciences, mathematics, physics, and chemistry; 2—spaces for the dissemination of sciences of a more museum-like or more interactive nature; 3—primary and secondary school connections; 4—science teacher training centers; 5—relevant activity in research in science education; 6—the existence of well-equipped didactic laboratories; and 7—links to numerous international projects, European, but not only, dedicated to the teaching and dissemination of science.

The reality briefly referred to above has allowed this doctoral degree to be one of the most sought-after at FCUP and, in the meantime, has also contributed to the production of dozens of theses, with the widespread dissemination of publications in specialty journals. Most research works focus on science teaching, with methodologically evaluated testing of new didactic practices supported by relevant paradigms such as citizen science, problem-solving learning, or STEM.

It would only be fair to end this short description by referring to some fragile aspects of this doctoral degree. One of the most relevant is a relatively large dropout rate, mainly due to economic reasons on the part of students. Many students are student workers, typically teachers, who often fail to reach the end of the course despite their skills and dedication, among other things, because they cannot pay the high tuition fees. The opposite happens with students with funding (for tuition fees and the possibility to dedicate themselves to the course full-time). These, without exception, successfully reach the end of the course. What could be an incentive for primary and secondary school teachers also enrolled in this course? Their career progression has also yet to be much supported by the government, encouraging some students to drop out of the course.

Finally, it is essential to highlight the possibilities of internationalization already being carried out (many international students, mainly from Brazil and other Portuguese-speaking countries), but whose scope we intend to extend even more.

For the above reasons, this cycle of studies leading to a doctoral degree represents an added value for the national and international community in science teaching and dissemination. We have already come some way and have all the conditions, including enthusiasm, to walk further ahead and better.

4.2.5. Case 5: University of Minho: Master's in Science Communication

The master's course at Minho University focuses on science communication more than science dissemination (codification_UM_M). Its syllabus stresses the various forms of science communication, preparing students both theoretically and practically for the challenges of science communication in multiple settings. It benefits from being born out of a partnership between two different schools within Minho University: communication and natural sciences. Thus, it can provide insightful perspectives on science communication, combining various levels of knowledge and skills.

A distinctive feature of this master's is that it is open to anyone who graduated, regardless of the scientific area of graduation. Therefore, classes are made up of students with very different backgrounds. This enriches the debates in class and the learning opportunities for students and teachers. The multidisciplinary context of the teaching

practice is one of the most challenging aspects for teachers, but it also adds value for students and teachers. To complete their master's, students can either write a dissertation, develop an action research plan, enroll in a professional training experience, or write a report.

The master's course has the advantage of being offered in a geographic area of scientific and technological development. In its area of influence, there are several institutions that develop scientific research and need to broaden their outreach and communicate their activities. There is an increasing recognition of the value of science communication among scientific institutions. Even though some institutions still need to be made aware of the importance of having people with specific training in the field, others are acknowledging its relevance. Therefore, there are several employment opportunities for the students because some institutions need trained professionals to professionalize their science communication activities.

However, this recognition remains enclosed chiefly in the scientific circuits and only reaches some of society, namely potential students. This may reflect the lack of visibility and scientific literacy in society in general and in undergraduate students. Possibly fearing its alleged complexity and lack of excitement, science and science communication, in particular, is not seen as an attractive future job. Our candidates are mainly people with a previous strong interest in science communication, generally due to previous professional experiences. It has been more difficult to raise interest among other freshly graduated students to attract them to this professional ground. This could be one of the significant challenges for the master's degree program: widening the scope of potential students by increasing the recruitment base of the master's degree program. But this requires more than just advertising the master's; it also requires changing the general mindset regarding science.

4.3. Global Characterization of the Programs

At this point, a comprehensive analysis of the data from the programs under scrutiny is conducted, with no intention of directly comparing the programs. In other words, a mapping of postgraduate training in science communication in Portugal is carried out as a whole. The outcomes obtained from individual questionnaires administered to each postgraduate program director have provided insights into various aspects, including student and teacher profiles, partnerships established with society, and academic outputs. These findings are visually represented in Figure 2 through pie charts, illustrating the distribution of percentages for enhanced clarity.

4.3.1. Students' and Teachers' Personal and Academic Profiles

The initial question seeks to discern the postgraduate science communication training participants in Portugal. The results are out of a total of 286 students undergoing science communication training; 72% are Portuguese, 8% hail from Portuguese-speaking countries (CPLP), and the remaining 20% represent diverse nationalities (see Figure 2).

Regarding the age distribution among students, 50% fall within the 20–29 age bracket, 27% are aged between 30 and 39, 17% fall within the 40–49 range, and 5% are between 50 and 59. Only 1% of students are 60 or older (Figure 2).

Regarding gender distribution, existing research provides varying perspectives on the involvement of female or minority scientists in outreach spaces [26]. Some studies suggest that female scientists or minorities are more commonly found in these spaces, while others indicate a higher likelihood of male scientists engaging in public outreach [27]. Additionally, senior scientists tend to be more actively involved in public engagement, which is attributed to their advanced career stages [28]. The research also suggests variations in public engagement practices among scientists based on their disciplines, with higher engagement observed in the social and environmental sciences and biology or medicine [29].

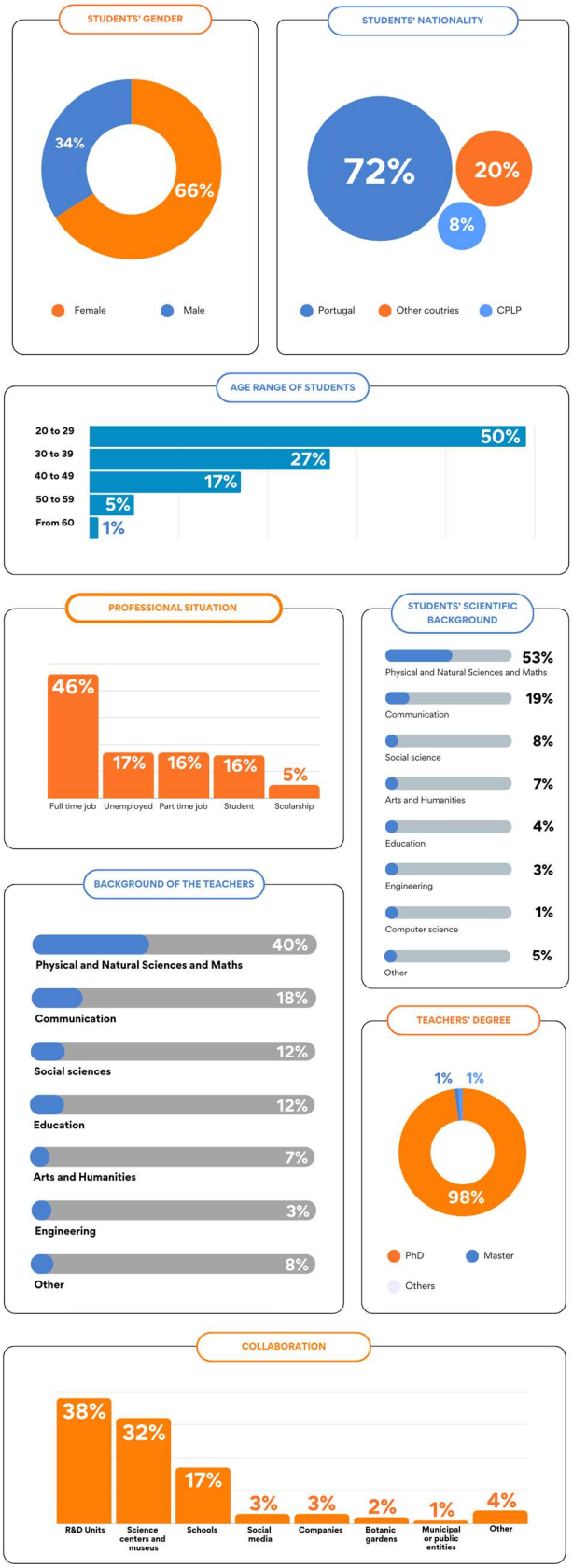

Figure 2. Students' and teachers' personal and academic profiles.

In our study, focusing on student profiles, we found that 66% are female and 34% are male, aligning with the findings of Ecklund et al. [29]. This aligns with a report by

the British Science Association (2016) on science communication and public engagement in the United Kingdom (UK) [27]. The report compared the demographics of science communicators with national data, revealing a majority of female respondents (66%), with the majority falling within the age range of 25–44 (68%).

Regarding the professional status of students, our results indicate that in Portugal, the majority (46%) are employed full-time, 17% are unemployed, 16% hold part-time jobs or are students, and only 5% are beneficiaries of scholarships (Figure 2).

Lastly, the academic backgrounds of students enrolled in these programs are distributed as follows (Figure 2): Observed in the distribution, physical and natural sciences, along with mathematics, constitute 53% of the academic backgrounds, followed by 19% in communications, 8% in social sciences, 7% in arts and humanities, 5% in other fields, 4% in education, 3% in engineering, and 1% in computer sciences. This outcome is expected, given that the postgraduate programs under analysis originated in science departments. Consequently, most students naturally gravitate toward these programs due to their close association with scientific disciplines.

A collective of 74 teachers delivers science communication postgraduate programs in the analyzed courses. Regarding academic qualifications, the vast majority (98%) of these instructors hold a PhD, only 1% have a master's degree, and the remaining 1% possess alternative credentials. In terms of the teachers' academic backgrounds, the breakdown reveals that 40% have roots in physical and natural sciences and mathematics, 18% in communications, 12% in both social sciences and education, 7% in arts and humanities, 8% in other fields, and 3% in engineering (see Figure 2).

4.3.2. Partnerships/Connections Established with Society

The main conclusion is that the established partnerships and connections are diversified. Indeed, 38% are collaborations with research and development (R&D) units, 32% with science centers and museums, 17% with schools, 3% with social media and companies, 2% with botanic gardens, 1% with municipal or public entities, and 4% with others (see Figure 3).

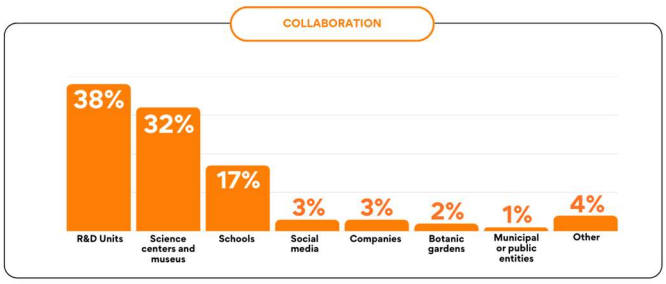

Figure 3. Partnerships/connections established with society.

4.3.3. Academic Outputs

Figure 4 illustrates the distribution of academic outputs (58%), categorizing them into theoretical and practical (69%), theoretical (17%), and practical (15%). When analyzing applied outputs (42%), the focus is on services (51%), products (18%), and a combination of both (10%) and other outputs (21%).

The study results show that theses and dissertations predominantly fall within the theoretical (and practical) domain, with a significant emphasis on services, followed by products. These findings align with the observed progression from affective to identity strands.

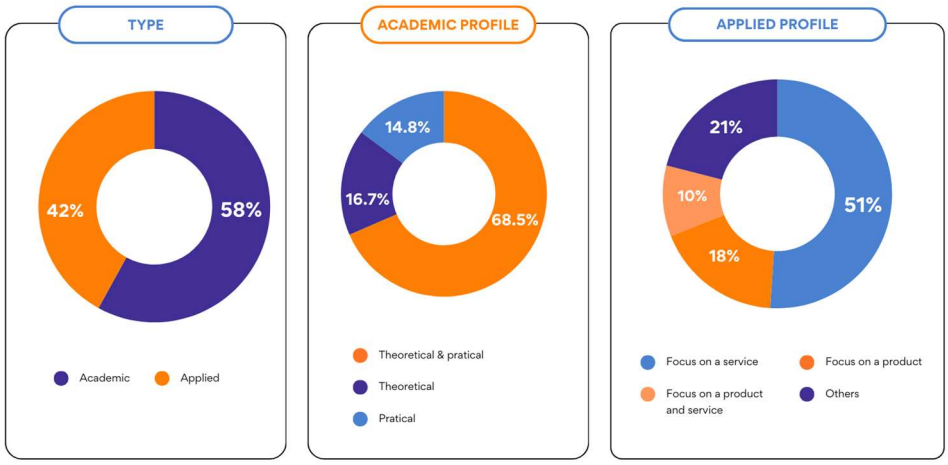

Figure 4. Academic outputs.

5. Conclusions

The HE institutions in Portugal are expected to establish a shared understanding of science communication and collaborate on enhancing the integration of science communication training at early career stages for scientists, extending beyond the confines of specific research projects.

The study analyzes science communication postgraduation training in Portuguese public higher education, arising from content analysis of written documents and questionnaires (open-ended questions). The study's foundation lies in data obtained from documents and questionnaires, facilitating a comprehensive examination of science communication training in Portuguese higher education institutions, including master's and PhD programs. By employing qualitative and quantitative analyses, the study offers a nuanced understanding of science communication training within the Portuguese higher education landscape, contributing valuable insights for academic and practical applications.

The results presented in Section 4.1 outline five postgraduation programs, including a master's in science communication at NOVA University of Lisbon, a master's course in "scientific culture and the dissemination of science" at Lisbon University; a master's in science education and dissemination and a doctorate in science education and communication of the University of Porto; and the master's degree in science communication at the University of Minho. The University of Minho's master's in science communication prepares individuals for communication roles in scientific institutions. It offers multidisciplinary training and fosters collaboration with regional and national institutions, linking academia with society.

The University of Porto offers two postgraduate programs that involve teachers from diverse science fields, emphasize robust science teaching and outreach training, integrate research closely tied to physical and natural sciences, and foster multidisciplinary teaching and popularization skills. Lisbon University offers the master in scientific culture and science dissemination, a collaborative effort across university schools, fostering multidisciplinary knowledge and aiming to train professionals in promoting scientific culture. Finally, the master's in science communication at NOVA University of Lisbon is a collaborative initiative between two departments, fostering discussions on the science-society relationship and offering training in communication strategies.

The directors of Portuguese postgraduate programs in science communication highlight evolving strengths and challenges. NOVA University of Lisbon's program emphasizes theoretical understanding and practical skills, adapting to changes in science communication. Lisbon University fosters interdisciplinary collaboration but faces recruitment and advertising challenges. Porto University's master's uniquely combines science education and communication, attracting an international student body. The University of Porto's doctorate contributes to research but struggles with high dropout rates due to

financial constraints. The University of Minho's master's stresses practical training but faces difficulty attracting students beyond those already interested in science communication, suggesting a need for broader societal recognition. In summary, the directors offer a comprehensive overview of the landscape of science communication training in Portugal, highlighting achievements and improvement areas. Through continued innovation and collaboration, these programs are poised to address the evolving needs of professionals in science communication, both nationally and internationally.

A comprehensive analysis of Portuguese postgraduate science communication program data is presented without direct comparisons. Insights from individual questionnaires to program directors cover student and teacher demographics, educational objectives, and societal partnerships, which are visually depicted using pie charts. Student profiles reveal a majority of Portuguese (72%), aged 20–29 (49%), with 66% female. Instructors, predominantly holding a PhD (98%), hail mainly from physical and natural sciences (41%). Educational goals span participatory, affective, reflective, identity, content, and method strands, with partnerships ranging from research and development (39%) to science centers and museums (33%).

Despite its size, Portugal boasts a considerable array of opportunities in science communication across the country, catering to diverse audiences and profiles. The offerings vary in context and academic level (master's and PhD), featuring well-qualified teaching personnel. The nation exhibits vibrant dynamism in this domain, evident in the noteworthy theses and dissertations completed in the last few years. While we have not explored the specifics of these academic works, further in-depth research in this field would be invaluable.

Beyond academic theses and dissertations, numerous national initiatives contribute to science communication in Portugal, such as the Ciência Viva Science Centers Network and the annual SciComPt conference. Higher education institutions actively engage in science outreach and society-focused programs, exemplified by events like the Research Summit and Summer Academy at universities like Aveiro and Porto. Although the University of Aveiro previously offered a master's degree in science communication, it was discontinued in 2013.

In essence, despite the positive instances mentioned, the field of science communication in Portugal is still in its early developmental stages. Institutions must establish a shared understanding of science communication, emphasizing the enhancement of student learning in research environments throughout the curriculum, not limited to final-year projects.

The findings provide significant insights into the comprehensiveness of curricula across five science communication post-graduate programs within four public universities in Portugal. Nonetheless, the absence of input from masters and PhD students hinders the study's potential to enrich academic discourse and may constrain interpretations of the presented results. Future research endeavors should prioritize integrating diverse data collection methods, including soliciting students' perspectives (e.g., collected with individual interviews) and incorporating additional sources such as theses and dissertations from the analyzed programs (e.g., data collection procedures).

6. Further Development of Post-Graduation in Science Communication in Portugal

The current state of science communication training in Portugal is promising [30]. However, despite the positive instances highlighted earlier, a set of recommendations needs to be systematically addressed and coordinated by critical stakeholders across the four primary spheres of higher education: policymakers, institutional leaders, individual academics, and coordinators of research units/centers [31].

Addressing this, key stakeholders across university spheres, including politicians [32], institutional leaders, individual academics, and research unit/center coordinators, must collaboratively formulate and implement recommendations to propel the advancement of science communication education in the country.

Recommendation 1. *Ensure effective institutional policies to reinforce the structures for teaching and research about science communication in Portugal.*

As observed in the majority of the reviewed programs (for example, see Figure 3. Partnerships/connections established with society), fostering connections between postgraduate training programs and diverse stakeholders in science communication and science education is crucial. Higher education institutions (HEIs) should integrate clear guidelines for embracing a science communication identity into their teaching and research strategies. Institutional policies within HEIs must establish robust planning and review processes to ensure that the curriculum is consistently shaped by this learning approach [2].

Postgraduate programs in science communication should provide a cohesive and progressive training experience, guiding students in the art of researching in science communication and education. This journey should culminate in the development of dissertations and PhD theses, necessitating substantial research-related activities from students starting in the early stages of their postgraduate studies.

Recommendation 2. *Value the specific science communication training as a criterion to admit candidates to science communication and outreach positions.*

According to the director at the NOVA University of Lisbon, there has been a notable shift in the motivations of postgraduate students in recent times. While many sought (and successfully achieved) a career change in the past, today's doctoral students are increasingly considering science communication as their initial career choice. In the evolving landscape of communication roles, it becomes imperative to emphasize the value of the science communication component. Establishing appropriate criteria for evaluating science communication skills is crucial, especially for positions like those in university science offices. Calls for applications should explicitly highlight the importance of training in science communication, acting as a catalyst to attract more candidates to postgraduate programs.

In Portugal, individuals pursuing a master's degree in science communication must hold a degree in any disciplinary area, with a particular emphasis on physical sciences, natural sciences, mathematics, and communication. Beyond the academic realm, diverse career opportunities await, including paths in journalism/communication and positions within science communication entities like science centers, museums, botanical gardens, and more.

Recommendation 3. *Provide financial support to develop research in science communication.*

As highlighted by a director, a significant challenge in the realm of science communication lies in the notable dropout rate, primarily attributed to economic constraints faced by students. Thus, the predominant goal extends beyond merely attracting new students to this research field; it involves providing support to ensure the successful completion of their doctoral theses. To foster the success of science communication in Portugal, academics must secure dedicated funding streams from national agencies, such as the "Fundação para a Ciência e Tecnologia" (FCT), specifically designed to support and sustain research in this domain robustly. The aim is to generate new insights into teaching and learning strategies anchored in science communication, necessitating a commitment to developing knowledge in this area.

Moreover, increased investment is imperative, spanning journalism and media, as a means to elevate the presence of science and technology in the media landscape. This approach not only contributes to public understanding but also serves to attract more young individuals to pursue STEAM programs in higher education. In the contemporary societal context, it is crucial to actively contribute to public comprehension of science while concurrently addressing the need to counter misconceptions and fake news prevalent in society.

Recommendation 4. *Raise the culture of science communication training in higher education.*

Higher education institutions, encompassing entities such as the rectory, departments, and research centers, are responsible for cultivating awareness among students and academics regarding the significance of science communication for public understanding of

science. It becomes imperative to reinforce awareness about the ongoing research within the campus and explore avenues for its dissemination to society, including R&D units, science centers and museums, schools, social media, companies, botanical gardens, and municipal or public entities, among others. Achieving this requires involving external partners in collaborative projects within a research-based educational environment, as mentioned by the directors, and also by content analysis of the documents of programs (see Figure 3. Partnerships/connections established with society).

Establishing a culture of science communication is attainable by effectively communicating the research expertise of academics and showcasing partnerships with industry, particularly in the realms of knowledge transfer and innovation. Additionally, creating opportunities for students, be it at the master's or PhD level, to engage with research labs fosters this culture. The nature of this engagement may vary based on the academic level, lab availability, researchers' involvement, and the level of commitment from each school or department.

Author Contributions: Conceptualization, C.G. (Cecília Guerra), A.M. and P.P.; methodology, C.G. (Cecília Guerra), A.M. and P.P.; validation, C.G. (Cecília Guerra), A.M. and P.P.; C.G. (Cecília Galvão), C.F., A.G., A.S., J.C.P., P.S.C. and E.C.e.S.; formal analysis, C.G. (Cecília Guerra), A.M. and P.P.; investigation, C.G. (Cecília Guerra), A.M. and P.P.; resources, C.G. (Cecília Guerra); A.M., P.P., C.G. (Cecília Galvão), C.F., A.G., A.S., J.C.P., P.S.C. and E.C.e.S.; data curation, P.P.; writing—original draft preparation, C.G. (Cecília Guerra); writing—review and editing, C.G. (Cecília Guerra); A.M., P.P.; C.G. (Cecília Galvão), C.F., A.G., A.S., J.C.P., P.S.C. and E.C.e.S.; visualization, P.P.; supervision, C.G. (Cecília Guerra), A.M. and P.P.; project administration, C.G. (Cecília Guerra), A.M. and P.P.; funding acquisition, C.G. (Cecília Guerra). All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by National Funds through FCT—Fundação para a Ciência e a Tecnologia, I.P., under the project UIDB/00194/2020 (CIDTFF), UIDB/04107/2020 (UIDEF) and UIDB/04968/2020 (IFIMUP).The APC was funded by National Funds through FCT—Fundação para a Ciência e a Tecnologia, I.P., under the project UIDB/00194/2020 (CIDTFF).

Institutional Review Board Statement: Ethical review and approval were waived for this study due to data protection being assured by following the institutional protocol that regulates the practice component of PST training, including data collection procedures.

Informed Consent Statement: Informed consent was obtained from all participants through a form delivered to the directors.

Data Availability Statement: More information regarding data collection and coded data can be provided from the corresponding author upon reasonable request.

Acknowledgments: We would like to extend our sincere thanks to Lais Rodrigues (laishgr@ua.pt) substantial contribution, for her assistance with the graphic design elements of this paper. Her skillful design work has greatly enhanced the presentation of the research findings.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Davies, S.R. An empirical and conceptual note on science communication's role in society. *Sci. Commun.* **2021**, *43*, 116–133. [CrossRef]
2. Baram-Tsabari, A.; Lewenstein, B.V. Science communication training: What are we trying to teach? *Int. J. Sci. Educ.* **2017**, *7*, 285–300. [CrossRef]
3. Mieg, H.A.; Ambos, E.; Brew, A.; Galli, D.; Lehmann, J. (Eds.) *The Cambridge Handbook of Undergraduate Research*; Cambridge University Press: Cambridge, UK, 2022.
4. Direção-Geral de Estatísticas da. Educação e Ciência (DGEEC). 2020. Available online: https://www.dgeec.mec.pt/np4/home (accessed on 1 October 2023).

5. Organização Para a Cooperação e Desenvolvimento Económico (OCDE). 2006. Available online: https://www.dgae.gov.pt/servicos/comercio-internacional-e-relacoes-internacionais/multilaterais/organizacao-para-a-cooperacao-e-desenvolvimento-economico-ocde-.aspx (accessed on 1 September 2023).
6. Fonseca, M.; Encarnação, S.; Justino, E. Shrinking higher education systems: Portugal, figures, and policies. In *Higher Education in Societies*; Brill: Leiden, The Netherlands, 2014; pp. 127–147.
7. Besley, J.C.; O'Hara, K.; Dudo, A. Strategic science communication as planned behavior: Understanding scientists' willingness to choose specific tactics. *PLoS ONE* **2019**, *14*, e0224039. [CrossRef] [PubMed]
8. Clark, G.; Russell, J.; Enyeart, P.; Gracia, B.; Wessel, A.; Jarmoskaite, I.; Polioudakis, D.; Stuart, Y.; Gonzalez, T.; MacKrell, A.; et al. Science educational outreach programs that benefit students and scientists. *PLoS Biol.* **2016**, *14*, e1002368. [CrossRef] [PubMed]
9. Ritchie, T.S.; McCartney, M. Providing transferable, professional skills for the next generation of scientific professionals through an outreach opportunity. *J. STEM Outreach* **2019**, *2*, 1–13. [CrossRef]
10. Burns, T.W.; O'Connor, D.J.; Stocklmayer, S. Science communication: A contemporary definition. *Public Underst. Sci.* **2003**, *12*, 183–202. [CrossRef]
11. Silva, J.; Bultitude, K. Best practice in communications training for public engagement with science, technology, engineering and mathematics. *J. Sci. Commun.* **2009**, *8*, A03. [CrossRef]
12. Ham, B. Public engagement: Workshops build the story-telling skills of scientists. *Science* **2008**, *320*, 463–464. [CrossRef]
13. Latimore, J.A.; Dreelin, E.A.; Burroughs, J.P. Outreach and Engagement Education for Graduate Students in Natural Resources: Developing a Course to Enrich a Graduate Outreach Requirement. *J. High. Educ. Outreach Engagem.* **2014**, *18*, 129–154.
14. Miller, S.; Fahy, D.; Team, T.E. Can science communication workshops train scientists for reflexive public engagement? The ESConet experience. *Sci. Commun.* **2009**, *31*, 116–126. [CrossRef]
15. Mulder, H.A.J.; Longnecker, N.; Davis, L.S. The state of science communication programs at universities around the world. *Sci. Commun.* **2008**, *30*, 277–287. [CrossRef]
16. Dudo, A.; Besley, J.C.; Yuan, S. Science communication training in North America: Preparing whom to do what with what effect? *Sci. Commun.* **2021**, *43*, 33–63. [CrossRef]
17. Trench, B.; Miller, S. Policies and practices in supporting scientists' public communication through training. *Sci. Public Policy* **2012**, *39*, 722–731. [CrossRef]
18. Akin, H.; Rodgers, S.; Schultz, J. Science communication training as information seeking and processing: A theoretical approach to training early-career scientists. *J. Sci. Commun.* **2021**, *20*, A06. [CrossRef]
19. Bell, P.; Lewenstein, B.; Shouse, A.; Feder, M.; Committee on Learning Science in Informal Environments; National Research Council. *Learning Science in Informal Environments: People, Places, and Pursuits*; National Academies Press: Washington, DC, USA, 2009.
20. Sherman, R.R.; Webb, R.B. Qualitative research in education: A focus. In *Qualitative Research in Education*; Routledge: London, UK, 2004; pp. 2–21.
21. Bowen, G.A. Document analysis as a qualitative research method. *Qual. Res. J.* **2009**, *9*, 27–40. [CrossRef]
22. Cohen, L.; Manion, L.; Morrison, K. *Research Methods in Education*; Routledge: London, UK, 2002.
23. Creswell, J.W.; Poth, C.N. *Qualitative Inquiry and Research Design: Choosing among Five Approaches*; Sage Publications: Thousand Oaks, CA, USA, 2016.
24. Bogdan, R.; Biklen, S.K. *Qualitative Research for Education*; Allyn & Bacon: Boston, MA, USA, 1997.
25. Marcinkowski, F.; Kohring, M.; Fürst, S.; Friedrichsmeier, A. Organizational influence on scientists' efforts to go public: An empirical investigation. *Sci. Commun.* **2014**, *36*, 56–80. [CrossRef]
26. Besley, J.C.; Dudo, A.; Storksdieck, M. Scientists' views about communication training. *J. Res. Sci. Teach.* **2015**, *52*, 199–220. [CrossRef]
27. British Science Association. *A Changing Sector: Where Is Science Communication Now*; BSA: London, UK, 2016.
28. Torres-Albero, C.; Fernández-Esquinas, M.; Rey-Rocha, J.; Martín-Sempere, M.J. Dissemination practices in the Spanish research system: Scientists trapped in a golden cage. *Public Underst. Sci.* **2011**, *20*, 12–25. [CrossRef]
29. Ecklund, E.H.; James, S.A.; Lincoln, A.E. How academic biologists and physicists view science outreach. *PLoS ONE* **2012**, *7*, e36240. [CrossRef]
30. Entradas, M.; Bauer, M.M. Mobilisation for public engagement: Benchmarking the practices of research institutes. *Public Underst. Sci.* **2017**, *26*, 771–788. [CrossRef]
31. Grunig, J.E. The development of public relations research in the United States and its status in communication science. Ist Public Relations eine Wissenschaft? *Eine Einführung* **1992**, 103–132.
32. Dawson, E.; Hughes, S.; Lock, S.J.; Wahome, M. Exploring the politics of science communication research: Looking at science communication from a social justice perspective. *J. Sci. Commun.* **2022**, *21*, C05. [CrossRef]