Connecting people with plants: exploring the role of science communication within botanic gardens

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Abstract

Botanic gardens play a pivotal role in fostering connections, appreciation, and understanding between people and plants. The prominence of science communication in these institutions is rising, aiming to raise awareness and understanding of biodiversity, conservation, and the sustainable use of biological resources.

Recognising gaps in knowledge regarding science communication practices and practitioners within botanic gardens, this thesis seeks to explore these practices within a European context, with a more in-depth examination of the UK and Portugal. Furthermore, it intends to investigate how communicators working in botanic gardens in these countries embody science communication.

Science communication practices were explored through a mixed-methods approach, drawing on data from 113 national reports representing 27 countries. This analysis enabled the identification and categorisation of science communication activities and audiences. Subsequently, a survey based on these categories was distributed to each country's representative in order to quantify the occurrence of these activities. In addition, 28 semi-structured interviews were conducted in the UK and Portugal to investigate science communication practices in these two countries.

The analysis of the national reports revealed 16 categories for science communication activities and 18 categories for target audiences. The survey assessed 14 activity categories and 16 audience categories. Five activity categories and three audience categories were found to be common across the surveyed countries. UK showed more diversity in science communication activities and audiences.

Participants exhibited diverse perspectives on the concepts of science communication, with some demonstrating a narrow view of the field. Among participants, five communication aims were identified, with the most frequently reported being 'create an engaging environment' and 'facilitate learning.' Seven communication roles were identified, with 'educator,' 'engager,' and 'translator' roles being the most frequent. Regarding the interaction between botanic gardens and society, three conceptualizations were identified: 'supplying,' the most prevalent, 'collaborative,' and 'co-created'.

This thesis provides an insightful framework for botanic gardens' practices in science communication by cataloguing the types of activities offered to visitors and target audiences. Although participatory approaches were found to play a role in botanic gardens communication, the results indicated that science communication practices in these institutions tend to be more aligned with one-way approaches. This work contributes to a deeper understanding of the communication practices in

botanic gardens, which could inform the development of science communication strategies for these institutions.

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This thesis is dedicated to all women with endometriosis and adenomyosis.

Contents

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

Humans and plants have evolved together (*sensu lato*), shaping their shared history. A dramatic change in this planetary co-habiting took place 13,000 - 10,000 years ago, when humans domesticated plants enabling the transition from a nomadic to a sedentary lifestyle (Purugganan and Fuller, 2009). Thereafter, humans embarked on journey that involved developing skills, refining tastes, and attributing various purposes to plants. This dynamic extends from the cultivation of crops essential for the sustenance of our species, to modification of the aesthetic features of ornamental plants.

Throughout this plant domestication journey, specific places have been created with the specific intention of hosting plant collections for cultivation, experimentation, and research purposes: the botanic gardens. The contemporary concept of botanic gardens, started in 16th century Italy and, subsequently, botanic gardens spread throughout Europe and worldwide (Faraji and Karimi, 2022). First known as physic gardens, the initial purpose of these institutions was to host plants of pharmacological interest for medical studies. Later their remit expanded to include hosting collections of native and exotic plants, plant acclimation sites, and also display of the evolutionary relationships between plants, with botanic gardens becoming more complex sites alongside the development of botanical sciences (Rakow and Lee, 2015).

The conceptualisation of botanic gardens has evolved over time, encompassing social, cultural and scientific features. During imperial and colonial periods, plants and botanical artifacts from around the world were brought to be cultivated and deposited, respectively, in these institutions (Nesbitt and Cornish, 2016), contributing to the enrichment of botanical knowledge and the development of plant collections. A major change that shaped the future trajectory of these institutions was the decision to open their doors to the public. For instance, the Royal Botanic Gardens Kew opened to the public in 1840, while the Botanic Garden of the University of Coimbra, developed in 1772, integrated the so-called ‘promenade’ where the public would stroll. Opening to the public marked the beginning of a new era for botanic gardens, transforming them from exclusive, scientific institutions into green spaces accessible to the public. Over time, the social role of botanic gardens has expanded, with plant conservation and education being incorporated into their mission, allowing these institutions to attend to the changing needs of society and stay relevant (Blackmore, 2017).

The social role of botanic gardens encompasses provision of both educational and outreach activities, as well as providing recreational services to their visitors (Krishnan and Novy, 2017). Nowadays, botanic gardens are regarded as a 'gateway to information on plant diversity' (Sharrock, Oldfield and Wilson, 2014, p.39), fostering people's connection with plants (Krishnan *et al.*, 2019), and enhancing the interplay between the public and plant-related questions (Botanic Gardens Conservation International, no date a).

Today, the Botanic Gardens Conservation International (BGCI) defines botanic gardens as 'institutions holding documented collections of living plants for the purpose of scientific research, conservation, display, and education' (Botanic Gardens Conservation International, no date b). While the BGCI definition for a botanic garden is widely accepted, it is broad enough to include various types of institutions, such arboreta, botanical parks, or environmental charities such as Eden Project or Fossil Plant, in the UK. For the purpose of this thesis, I have adopted a more specific definition: a botanic garden is considered an institution that not only meets the BGCI criteria but is also explicitly identified as a botanic garden, with the words 'botanic garden' included in its name. This may reflect the way people typically identify such institutions and distinguish them from other types of gardens or plant-focused visitor attractions.

This thesis seeks to address botanic gardens as hubs for engaging the public with plants and related sciences. Drawing on data from the annual reports of European botanic gardens and interviews with institutions in the United Kingdom and Portugal, this study explores the role of science communication in these institutions.

1.1 The context of this research

Europe host the largest number of botanic gardens globally, with over 900 institutions that collectively welcome more than 120 million visitors annually (Botanic Gardens Conservation International, no date c). Although the focus of plant collections varies considerably among botanic gardens, when entering many of these uniquely curated green spaces, visitors embark on a journey around the world by being surrounded with plants from all parts of the globe. It is in this moment that visitors experience the primary line of knowledge shared by botanic gardens: the diversity of plant species, along with their respective scientific and vernacular names, origin, and botanic family. Interpretation panels are commonly placed to provide additional information about the realm of plants and the botanic garden. Furthermore, the scope of information can extend beyond plants to encompass topics such as biodiversity conservation, climate change, or the sustainable use of biological resources.

Botanic gardens boost visitor's experiences and interactions with plants by offering a variety of activities that allow them to engage with scientific themes such as botany, environmental sustainability, biodiversity loss, climate change (Blackmore, 2017) or to tackle the plant awareness disparity (Parsley, 2020), previously referred to as plant blindness. Plant awareness disparity is defined as 'the inability to see or notice the plants in one's own environment' that leads to an inability to recognize the importance of plants in the biosphere, and in human affairs and thus their ecological needs and conservation requirements (Wandersee and Schussler, 1999). In this context, diverse audiences can participate in different forms of activities shaped by the staff of botanic garden engaged in developing and carrying out science communication activities.

Therefore, botanic gardens emerge as relevant spaces for science communication, acting as prominent hubs for outreach and engagement activities. These green sanctuaries foster awareness and inspire a deeper connection between people and plants. However, the role of science communication within botanic gardens remains underexplored. This thesis seeks to address this gap.

1.2 Botanic gardens as hubs for science communication

Since the early 20th century, botanic gardens have been offering educational programmes to their visitors (Bayindir, 2023, refers to educational programmes in the New York Botanical Garden at least since 1910). Today, these institutions are widely recognised as prominent providers of education (Dodd and Jones, 2010), and at least 91% of them state education as a primary target (Bayindir, 2023). Moreover, they constitute a unique space for researchers and science communicators to develop communication and public engagement initiatives (Primack *et al.*, 2021). Therefore, botanic gardens act as hubs in the promotion of societal engagement within the plant world and associated sciences (Krishnan *et al.*, 2019; Sharrock, Oldfield and Wilson, 2014).

Within this frame, botanic gardens offer a wide range of activities designed to accomplish one of their primary missions: increasing the visibility of plants. Common activities in these institutions include guided tours, workshops (Dodd and Jones, 2010), exhibitions (Krishnan *et al.*, 2019), and events (Smith, 2019). Additionally, in these settings' other types of activities such as citizen science (Mulhauser and Gaille, 2024), science cafés, and co-creation (Alexopoulos and Moussouri, 2021) are also conducted. Diverse audiences such as school groups (Dodd and Jones, 2010), adults, families, and children (Bayindir, 2023) participate in these activities.

Anecdotally, botanic gardens often refer to their activities as educational. For instance, Willison (2006) proposed several educational approaches for engaging audiences in botanic gardens, including

experimental and cooperative learning, role play, participatory action research, and self-directed learning. In fact, many botanic gardens have been created in and are managed by universities, and their collections, staff, and spaces are often included in academic courses (Bennett, 2014). Although some of the methodologies employed by some botanic gardens, such as inquiry-based learning (Vančugovienė, Lehtinen and Södervik, 2024), originate from educational scholarship, the activities conducted by these institutions to, for, and among the public may be defined as science communication activities, unless they specifically support formal education.

Regardless of the term used – communication, education, non-formal or informal learning – employing the term 'science communication' may be advantageous. It offers an umbrella term for activities that typically are not viewed as educational but still inform and promote public engagement with plants. For example, social media efforts by botanic gardens can effectively engage the public and foster appreciation for plant life, even if they are not explicitly educational. In this thesis, science communication is conceptualised as all practices employed by the staff of botanic gardens to engage non-specialist audiences, as well as all vehicles used to disseminate information about plant and associated sciences. It therefore adopts an inclusive definition of science communication, similar to that proposed by Bucchi and Trench (2021) that aligns science communication along a spectrum including dissemination, dialogue and participation.

As early as 2005, a gap in the available data about botanic gardens educational and communication activities was identified, with most of the limited literature referring to individual study cases (Kneebone and Willison, 2007). In a recent review, Bayindir (2023) argues that there is still a scarcity of research published in peer-reviewed journals regarding the educational roles of botanic gardens, arguing for the need to investigate their educational practices. A few studies have tried to address this gap: Kneebone and Willison (2007) assessed methods used to communicate, and the number and types of audiences reached, among other questions, by analysing over 120 responses to a survey to botanic gardens worldwide. Similarly, Gaio-Oliveira, Delicado and Martins-Loução (2017), used a survey to document the activities and the target audiences reached by botanic gardens around the world. Although the details differed, both studies used questionaries with pre-defined categories, and did not address all activities that these institutions provide to the public, such as participatory activities or communication channels, such as garden apps. Possibly owing to the limited number of activities included as predefined choices in these surveys, neither study sought to investigate how botanic gardens used specific activities to reach target audiences, nor did they comprehensively map them. Furthermore, no studies were found that explore the intersection of science communication scholarship and its practice in botanic gardens. There is a gap in understanding how science

communication is perceived by practitioners within these institutions, and how the frameworks of science communication might be applied.

1.3 Research questions and aims

This thesis aims to understanding how science communication is implemented in botanic gardens and perceived by practitioners of within these institutions. Therefore, this study seeks to answer two main research questions concerning the role of science communication within botanic gardens:

RQ1: ***'How do botanic gardens reflect contemporary science communication practices?'***

This question seeks to identify and systematically categorise the existing activities of European botanic gardens and the audiences they seek to reach. Further detailed research focuses on Portuguese and British botanic garden communities to develop a detailed understanding of their activities and audiences. This will be achieved by following:

a) cataloguing the types of science communication activities and audiences presented in the national reports of European botanic gardens.
b) investigating the perceptions of the representatives responsible for the national reports about the relevance of science communication activities in botanic gardens.
c) exploring science communication activities and audiences at UK and Portuguese botanic gardens.
d) comparing how these science communication practices are reflected between Uk and Portuguese botanic gardens.

RQ2: 'How do communicators working in botanic gardens embody science communication within distinct cultures?'

This question seeks to deepen our understanding of the roles and procedures employed by communicators in botanic gardens in the United Kingdom and Portugal to communicate science to their audiences. This will be achieved by the following:

a) exploring how communicators working in botanic gardens understand their position as science communicators.

b) investigating the aims of the activities carried out by communicators working in botanic gardens.

c) analysing the roles adopted by communicators working in botanic gardens in relation to their audiences.

d) evaluating how communicators working in botanic gardens conceptualise the interaction between botanic gardens and society.

1.4 Outline of chapters

This thesis is composed of seven chapters, including this one (**Chapter 1**), which introduces the research context.

Chapter 2 provides a literature review of the scholarship on science communication relevant to this thesis. It offers a historical perspective on the paradigms and models of science communication, explores contemporary trends, and reflects on the intersections of science communication with related disciplines, namely public relations and science education. The chapter also examines what is already known about the characteristics of science communicators, including their aims, roles, and conceptualisations.

Chapter 3 outlines the methodological framework employed in this thesis. It presents the epistemological position adopted to conduct the research, the rationale behind the chosen methods, and the approaches to data collection and analysis. It describes the participants involved in this research and addresses the ethical considerations underpinning the study.

Chapter 4 is dedicated to presenting the results of RQ1. It shows a quantitative content analysis of the collected data, aiming to map and categorise the science communication activities and target audiences of European botanic gardens. It also presents a qualitative content analysis designed to explore in greater depth the science communication activities and audiences of botanic gardens, using UK and Portuguese institutions as case studies.

Chapter 5 focuses on presenting the results of RQ2. Drawing on a thematic analysis, it shows how interviewees perceive their work as either science communication or science education, the aims they purse when engaging with their audiences, the roles they adopt in relation to their audiences, and how they conceptualise the interaction between botanic gardens and society.

Chapter 6 provides a comprehensive discussion of the findings related to the two research questions, integrating them with the existing literature on the subject.

Chapter 7 concludes the thesis by summarising the key outcomes of the findings, discussing the implications and recommendations arising from the research, addressing the limitations of the study, and suggesting directions for future exploration.

1.5 Personal motivation

I have always been a nature enthusiast, but it was during my studies that I developed a fascination with plants. This has shaped my academic and professional path, leading me to work in a botanic garden, where I first had the opportunity to engage with botanic garden visitors. Through these experiences I became interested in the field of science communication. In fact, it was during an activity with the public that I had my eureka moment: I realised that I wanted to be a 'connector' between plants and people, as I am both a plants person and a people person. With an academic background in biology and a strong interest in directing my career towards public engagement with plants, nature and the environment, I decided to pursue a PhD in science communication.

Driven by my passion for fostering connections between people and plants, I wanted my PhD to focus on plant-related science communication. I also have a sentimental attachment to this type of institution, having previously worked in the education department of a botanical garden. In addition, my curiosity extends to studying the ways in which staff engage with the public. Therefore, botanic garden staff have been chosen as informants in this thesis due to their relevant work in the field.

Chapter 2

LITERATURE REVIEW

Science communication lacks an agreed and transversal definition in the community. For example, it may be defined as 'the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science (the AEIOU vowel analogy): Awareness, Enjoyment, Interest, Opinion-forming, and Understanding)' (Burns, O'Connor and Stocklmayer, 2003, p.190). Alternatively, science communication has been defined 'as organised actions aiming to communicate scientific knowledge, methodology, processes or practices in settings where non-scientists are a recognised part of the audience' (Davies and Horst, 2016). In a more recent conceptualisation, Bucchi and Trench (2021, p.8) proposed an inclusive definition for science communication, namely 'the social conversation around science', incorporating outreach, engagement, interactivity, co-creation, among various other applications. The multiple definitions of science communication suggest that mediators between science and society, such as science communicators in settings like media, research centres, science museums, or botanic gardens, may hold distinct conceptualisations about the field. Each context brings its own nuances, influencing how science communication may be perceived and practiced. Therefore, while some practitioners may view science communication as a more one-way communication from experts to the public, others may definite it more broadly to include two-way communication (Bultitude, 2011).

For instance, science communicators working in the media (e.g. science journalists) may focus on disseminating scientific knowledge to a boarder audience; this may include contemporary issues such as addressing misinformation and to a limited extent engaging with their audiences through new digital tools, such as comments functions or social media. At the other extreme, staff in research centres may place an emphasis on sharing cutting-edge scientific discoveries with peers and the public, including bringing the public directly into their work to shape research questions, or in other ways enhance the quality of the work. Sitting somewhere in between might be staff in a science museum who seek to create interactive exhibits to engage visitors with scientific themes and may engage directly with visitors to stimulate discussion and enhance learning. In botanic gardens, the focus may be on environmental education, to foster appreciation, understanding, and connection with plants and associated sciences. These hypothetical examples highlight the ways that the conceptualisations of science communication may vary significantly across contexts, shaped by, for example, specific goals,

target audiences, and institutional missions. In botanic gardens, the prominent use of the term 'environmental education' raises questions about the boundaries between science communication and science education within these institutions, as these two areas often overlap. Therefore, characterising science communication practices in botanic gardens and understanding how mediators in these settings conceptualise their place in science communication is a valuable contribution for the scholarship of this field.

2.1 Science communication: paradigms and models of communication

The field of science communication has evolved significantly over the past few decades, shaped by its paradigms - science literacy, public understanding of science, and science and society - and models of communication – deficit, dialogue, and participatory. These models, which are conceptualised as 'hypothetical constructions, by the initiators of communication processes, of the relations between the actors involved' (Bucchi and Trench, 2016, pp. 154) have developed over time, evolving from one-way transmission approaches to more dialogic forms (Weitkamp and Almeida, 2022) that intertwined with the three paradigms of science communication (Bauer, Allum and Miller, 2007). According to the authors, these paradigms reflect evolving societal needs and academic perspectives, each corresponding to a specific timeframe, an attributed problem, and the respective solution.

The 'science literacy' paradigm (from 1960s to mid-1980s) assumes that the general public lacks scientific knowledge, possessing what is often termed a 'knowledge deficit'. This paradigm posits that there should be increased efforts in science education throughout all stages of life to strengthen the relationship between science and society. It also suggests that due to this perceived ignorance, the public is deemed unqualified to engage in science policy decisions. Consequently, this paradigm advocated that enhancing scientific literacy will bridge this knowledge gap (Bauer, Allum and Miller, 2007).

In 1985, Bodmer led a report for the Royal Society that influenced the shift from 'science literacy' to 'public understanding of science' (1985 to mid-1990s) (Weitkamp and Almeida, 2022; Short, 2013). This paradigm emerged from the concern that the public's perception of science is not sufficiently positive, raising fears that citizens might become sceptical or even hostile towards science. While this paradigm shares the view of knowledge deficit from the 'science literacy paradigm', it introduces the concept of an attitudinal deficit. Consequently, the emphasis has shifted from merely assessing the public's scientific knowledge to examining their attitudes towards science. This paradigm is predicated

on the assumption that increased knowledge will lead to greater appreciation and support for science. (Bauer, Allum and Miller, 2007).

The deficit model

The idea of science communication emerged from the 'public understanding of science' paradigm, leading to the creation of strategies based on what is commonly referred to as the deficit model (Weitkamp and Almeida, 2022), a one-way approach suggesting that scientific experts hold essential and valid knowledge that non-experts lack (Reincke, Bredenoord and van Mil, 2020). The aim of science communication, according to this model, is to bridge the knowledge gap by transmitting information from experts to laypeople. It also presupposes that increased literacy or knowledge leads to more positive attitudes towards science, such as greater trust(Reincke, Bredenoord and van Mil, 2020). Despite its foundational role in the in early science communication strategies, the deficit model has faced significant criticism. Scholars such as (Suldovsky, 2016a) argue that it is simplistic, mostly ineffective, and improperly characterising individuals who do not support or trust science as ignorant. Additionally, (Reincke, Bredenoord and van Mil, 2020) critique the deficit model for its hierarchical, one-way communication approach, where scientific expertise is positioned as inherently superior, and marginalises other forms of knowledge.

The growing criticism of the science literacy and public understanding of science paradigms, often labelled as deficit models (Suldovsky, 2016), has prompted a shift in focus, marking the beginning of a new paradigm in science communication, namely 'science and society' (from mid 1990s onwards). Rather than attributing the issues to the public lack of knowledge, attention has turned to the biases held by scientific institutions and experts regarding an uninformed public (Bauer, Allum and Miller, 2007). On this matter, a report commissioned by the House of Lords (2000), made a significant contribution to the development of the field of science communication. This report, aimed at addressing the dynamics between science and society, recommended, among other things:

> *That direct dialogue with the public should move from being an optional add-on to science-based policymaking and to the activities of research organisations and learned institutions, and should become a normal and integral part of the process.*

Furthermore, it suggested approaches to enhance the dialogue between science voices and society, including activities that promote public understanding of science, as at that time, little was being done. Subsequently, based on this report, Dickson (2000) and Miller (2001) reflected on how the path forward should be directed. Dickson argued that merely replacing the deficit model with one close to a dialogue-based communication approach is not enough. The author asserted that empowering individuals to make or endorse properly informed decisions about knowledge production and application is essential. Miller argued that replacing a 'science-fact-and-process' deficit with a consultation model based on the premises of a deficit was not sufficient. He emphasised the importance of understanding why the original deficit model proved inadequate and warned against the misconception that the end of the deficit model would mean there was no knowledge deficit. Miller stressed the importance of respecting the hard-won knowledge of scientists and encouraged open debate and dialogue about controversial scientific topics. According to the author, The House of Lords report paved the path for open, transparent and comprehensive dialogue, discussion, and debate on the impact of science for individuals and society (Miller, 2001).

The dialogue model

In response to the shortcomings of top-down communication, which initially focused on conveying scientific facts and then promoting the benefits of science, there has been a growing adoption of horizontal strategies aimed at fostering better connections between science and society (Weitkamp and Almeida, 2022). Consequently, since the early 1990s, scholars have proposed novel models for the objectives of science communication. In the latter part of this decade, a new model for science communication emerged: the dialogue model. This model aimed to overcome the issues related to the deficit model (Bucchi and Trench, 2016). This model proposes that scientific knowledge should be shared between scientists and the various groups who have an interest in the topic area. It also asserts that cultural, experimental, and scientific knowledge, among others, should be accorded equal significance (Reincke, Bredenoord and van Mil, 2020; Bucchi and Trench, 2016). This encompasses seeking counsel on the specific practical applications or implications of scientific applications (Trench, 2008), and scientists and non-experts engage in mutual learning (Reincke, Bredenoord, and van Mil, 2020).

The participatory model

In the early 2000s, the so-called three-way model or participatory model emerged within science communication research as a mean to engage the public in addressing shared societal concerns (Metcalfe *et al.*, 2022). According to Trench (2008), the focus of this model shifted from the applications to the implications of science; it prioritises the process rather than any quantifiable outcome, and all involved parties have equal power in the deliberations and decisions. For Metcalfe *et al.* (2022, p.4), participatory science communication should be inclusive and democratic, and it occurs 'when scientists and/or science communicators interact with various publics in a dynamic process where different forms of knowledge and experiences are acknowledged, shared, valued and negotiated, and where power relations are levelled'.

While the dialogue model marks a significant shift from the deficit-based approach, the participatory model of science communication introduces a new dimension for science-society interaction, inviting the public to actively participate in science. Although the dialogue model emphasis equality, mutual trust, and mutual understanding to foster true collaboration between science communication practitioners and the public (Verhoeff and Kupper, 2020), the participatory model goes further by allowing the public to initiate and direct engagement, thereby shifting the power dynamics towards them (Metcalfe *et al.*, 2022). However, the practical implementation of the participatory model has been criticised by scholars. Metcalfe *et al.* (2022) questioned the effectiveness and authenticity of participatory science communication. The authors advocate for studies to uncover if there are still underlying power imbalances that limit genuine participation. Leitch (2022) challenges the adequacy of the traditional view of participatory science communication which is based on a direct collaboration between the scientific community and society. The author proposes the 4 P's - power (underlying structures), place (attachment and sense), pain (of target audience) and 'poisson' (communicators values and assumptions) – as key consideration for a true participatory science communication. Furthermore, a study conducted by Loureiro and Horta (2024), which analysed two case studies of public participation, revealed that deficit-based interactions might continue to be utilised.

Despite the questions raised regarding the practical implementation of the public participatory model of science communication, approaches such as co-creation and citizen science have been redefining the relationship between science and society, fostering public integration and shared ownership of scientific endeavours. Such approaches can present opportunities for citizens to participate in truly participatory science activities, or activities that offer more limited opportunities for participation, such as those where citizens collect data or co-create communication materials. Such activities may

take place in botanic gardens, so we turn now to an exploration of how these approaches may be understood and implemented.

Co-creation

As with many other concepts in the field of science communication, co-creation lacks a clear definition (Rock, McGuire and Rogers, 2018). However, it is primarily understood as a collaborative methodology used to shape both research and innovation process, as well as practices of science communication itself (Achiam, Kupper and Roche, 2022). How these activities are implemented is affected by the nature of the organisation carrying out co-creation. For example, for heritage organisations, co-creation happens when the institution works closely together with community partners from the start to define the goals of a particular project, with the aim of establish a shared purpose. The result is a project which is truly co-owned by both. And co-creation projects are therefore based on a recognition and development of both community and institutional needs (Alexopoulos and Moussouri, 2021).

Although botanic gardens are not typically classified as heritage organisations, they share significant similarities, and literature shows examples of co-creation in botanic gardens. For instance, the co-design of a virtual and augmented reality experiences with stakeholders and target users aimed to create an interactive connection between visitors and plants (Bettelli *et al.*, 2019). Similarly, a European project involving a large consortium of botanic gardens, universities, a plant conservation charity, and a research laboratory for technology and society co-created exhibitions, science cafes, and other activities focused on food security and sustainability, with representatives from diverse audiences, including those classified by them as 'hard-to-reach' (Alexopoulos and Moussouri, 2021).

Citizen science

Similarly to science communication, citizen science faces significant challenges in achieving a universal definition due to its theoretical, geographical, practical, and societal dimensions (Vohland *et al.*, 2021). The authors advocate that a narrow definition for citizen science risks excluding many activities that fall under the umbrella of citizen science, due to the differences among academic fields, along with other contributing factors. A useful definition comes from the European Association for Citizen Science which defines citizen science as 'projects [that] actively involve citizens in scientific endeavour that generates new knowledge or understanding' (European Citizen Science Association, no date). However, Giardullo *et al.* (2023), in their analysis of 157 European citizen science projects, reveal a gap between theory and practice, particularly in achieving public engagement. Many citizen science

projects struggle to move beyond superficial involvement, struggling to engage participants in a participatory way. This reflects challenges seen more broadly in the application of the participatory model of science communication.

Regarding botanic gardens, Chen and Sun (2018) argue that the practice of citizen science in these institutions bridges the gap between scientific research and public engagement, empowering citizens to act as active contributors to science. They argue that citizen science not only advances scientific knowledge but also fosters environmental education, changes behaviours, and builds connections between communities and nature. However, the potential of this participatory approach remains to be fully explored in botanic gardens (Martellos *et al.*, 2016). The most common projects under this umbrella found in these institutions are transcriptions of letters, transcriptions of specimens, and species monitoring (for example Kew Gardens), which lack truly participatory engagements.

Each science communication model – deficit, dialogue, and participatory – aligns with a communication approach: one-way, two-way, and three-way, respectively. While some may perceive this as an evolution in science communication, all three remain valuable within different contexts (Bauer, 2009; Trench, 2008; Short, 2013; Suldovsky, 2016; Tayeebwa, Wendo and Nakiwala, 2022). A recent framework, proposed by Bucchi and Trench (2021), comprises three base models for science communication: dissemination, dialogue, and participation. Each model encompasses its corresponding applications, with the filling of a knowledge deficit being one of the applications of the dissemination model. According to the authors, dissemination informs, raises awareness, and facilitates learning among members of the public regarding scientific findings (i.e., already established knowledge). Dialogue involves questioning, opinion-sharing, and discussion on scientific issues (applications and implications of knowledge), while participation entails sharing, creating, enjoying, and critiquing scientific processes (interpretation and (re)construction of knowledge).

However, despite shifts in the academic discourse around science communication, approaching audiences from a deficit model framing persists among science communication practitioners (Simis *et al.*, 2016). According to the authors, several factors contribute to this persistence, including its simplicity and ease of application, the way scientists conceptualise the 'public', the influence of institutional structures, and the lack of formal communication training for scientists – a perspective corroborated by Seethaler *et al.* (2019).

2.2. Intersection of science communication with other disciplines

The science communication discipline is inextricably linked to other fields, such as public relations and science education, where similar debates have occurred (Trench and Bucchi, 2010). The following two sections, namely 2.3.1 and 2.3.2., examine the relevance of these fields to this thesis.

2.2.1. Science communication and public relations

Public relations is recognised as a type of applied communication (Botan and Taylor, 2004), which relates to science communication to some extent (Autzen and Weitkamp, 2019). Public relations, like science communication, encompasses both an area of research and professional practice. It is also a relatively young academic field and bases its theoretical frameworks on models of communication (Botan and Taylor, 2004). Additionally, both fields lack a consensual definition among scholars and are instead umbrella terms that can include a wide range of both academic research and practices. Grunig and Hunt (1984) conceptualised public relations as the 'management of communication between an organisation and its publics'. Verčič *et al.* (2001) argued that the definition of public relations in the European context diverges from the US-oriented definition – 'relationship management' - and the authors incorporated new dimensions such as a concern with publics and the public sphere to the concept of public relations. A definition for it was also provided Long and Hazelton (in Wilcox and Cameron, 2013, p.7) as 'a communication function of management through which organisations adapt to, alter, or maintain their environment for the purpose of achieving organisational goals'. The authors advocate for an approach where public relations should promote open, two-way communication and mutual understanding. This suggests that both the target audiences and the organisation should alter their knowledge, attitudes and/or behaviours in the process.

The development of theory and practice in public relations and science communication shows parallels, intersections, and contrasts (VanDyke and Lee, 2020). Both public relations and science communication emphasise the significance of co-creational communication models, which encourage frank dialogue and participation. They both aim to connect with relevant publics, build trust-based relationships, foster strategic dialogue, and shared understating (Roberson, 2020; VanDyke and Lee, 2020). For example, an early and still widely used theoretical framework for public relations comprising four models was proposed by Grunig and Hunt (1984). This comprises: agentry/publicity, public information, two-way asymmetrical, and two-way symmetrical. In many ways similar to the science communication models referred in the Section 2.1, the first two models use a one-way approach to communication and the latter two approach communication from a more dialogic perspective. The first, press agentry draws on a propaganda type approach to disseminate information, while not typical

in science communication we can see these tactics deployed in some types of advocacy-oriented communication (e.g. the way science is deployed in some environmental campaigns). The second focuses on the sharing of information and has many similarities with dissemination approaches adopted in science communication.

Turning to the dialogic models of public relations, the two-way asymmetrical approach seeks to persuade the public to adopt the perspectives of the organisation. While it promotes a two-way communication, it is unbalanced and focuses on the organisation's interests rather mutual understanding; science communication activities may adopt this approach in situations where the aim is to educate the audience on specific topics, perhaps with the goal of changing their beliefs or behaviours. The two-way symmetrical approach emphasises mutual understanding between the organisation and its publics. Similar science communication approaches would focus on reciprocal dialogue and mutual understanding between scientists and the public, fostering a collaborative exchange of information.

2.2.2 Science communication and science education

The fields of science communication and science education are distinct academic disciplines, each with its own paradigms and theoretical frameworks. Nevertheless, there is considerable overlap between the two (de Vries and van der Sanden, 2016), making it sometimes challenging to fully distinguish them (Burns, O'Connor and Stocklmayer, 2003). Both disciplines emphasise engaging students in an interactive, inquiry-based, or project-based approach (Trench and Bucchi, 2010), and share the goal of improving science literacy (de Vries and van der Sanden, 2016).

Despite their similarities, there are key differences between the two disciplines. Typically, science education offers formal qualifications or certifications of acquired knowledge (de Vries and van der Sanden, 2016), whereas science communication does not. Conversely, science communication has transitioned from one-way communication paradigm to align with two-way (dialogue) and three-way (participation) communication approaches, a shift that has not occurred in science education (Perera and Stocklmayer, 2013).

Nevertheless, science education increasingly recognises the benefits of integrating approaches aligned with the non-one-way models of science communication into formal educational settings. For instance, Lubicz-Nawrocka (2023) demonstrates that curriculum co-creation in higher education fosters collaboration between students and academic staff, underpinned by values such as trust and empathy, which humanise education and facilitates innovative curriculum development. Similarly, Bovill (2020)

highlights the potential benefits of co-creation for higher education in creating more inclusive and democratic learning environments. However, the author acknowledges the significant challenge of applied it in larger class sizes, and the need for academic staff to adapt their pedagogical practices.

Science education can take place in formal or informal settings and contexts. Formal learning typically happens within educational or training institutions, follows structured learning objectives, and usually leads to certification, whereas informal learning lacks structured objectives and usually does not lead to certification (Rogers, 2014). Additionally, non-formal education, which also takes place outside traditional educational settings, follows structured learning objectives but does not usually result in certification (Rogers, 2014). The non-formal or informal approaches of science education are conducted in botanic gardens, institutions that despite their potential, are frequently overlooked as centres for education, although they draw large numbers of visitors, provide interactive learning environments, foster critical inquiry, and influence public attitudes towards nature, sustainability, and conservation (Sanders, Ryken and Stewart, 2018a). Regarding informal environmental education, Falk (2005) advocates to be effective it requires a robust infrastructure that integrates schools, free-choice learning venues like museums and parks, and media. The attributes of non-formal or informal science education are of equal importance in the context of science communication, which makes it necessary to gain an understanding of the position of botanic gardens in these two realms. Furthermore, it may help elucidate the potential roles of botanic gardens staff as science communicators and/or educators.

2.3 Science communication in practice

A diverse range of actors, including individuals such as scientists, science journalists, activists, freelancers, bloggers, YouTubers, influencers, podcasters, artists, or institutions such as governmental bodies, non-governmental organisations, academia (Wilkinson *et al.*, 2023; Faehnrich, Riedlinger and Weitkamp, 2020; National Academy of Sciences, 2017), science-based organisations, such as science centres and museums (Rodari and Merzagora, 2007) and botanic gardens (Gaio-Oliveira, Delicado and Martins-Loução, 2017), are recognised as playing key roles in mediating the relationship between science and society. Often, members of these communities are called science communicators, who according to the Association for Science Communicators (ASC) is ‘anyone who communicates to increase the impact of science in society’ (Association for Science Communicators, 2024).

One of the earliest attempts to map science communication activities was published in 2000, with the support of the Welcome Trust (Research International, 2000). The UK-focused report enumerated a wide range of activities, including media, courses, exhibitions, science fairs, festivals, talks, science shops, books, and discussion groups. Furthermore, participatory activities, such as hearings, citizen

juries, deliberative opinion polling, and consensus conferences are also being pointed out in the field of science communication (Weitkamp and Almeida, 2022).

2.3.1 Aims and audiences of science communicators

The science communicators who took part in the report from the Welcome Trust (Research International, 2000) cited a range of reasons for their engaging in communication activities, including the dissemination of scientific knowledge, the fostering of positive attitudes towards science, the promotion of the appreciation of the social and economic impact of science, and the advancement of the relevance of science for daily life. Other works have identified additional goals, including the creation of excitement, the dissemination of knowledge, the shaping of opinions and behaviours based on evidence, and the engagement of diverse groups in addressing complex societal problems (National Academy of Sciences, 2017). The Royal Society report (2006) identified that the primary reasons for scientists and engineers to engage with non-specialist audiences are to ensure the public is better informed about science and technology, to raise awareness about science or the specific topic, to contribute to public debates about science and scientific issues, and to be accountable for the use of public funds. A recent study by Wilkinson *et al.* (2023) identified a range of motivations for diverse forms of science communication. These include the desire to foster enthusiasm for the topic, educate the public, combat misinformation, or because science communication is part of one's professional role. Additionally, some participants indicated that they were motivated by the prospect of collaborating with other organisations.

Regarding the audiences of science communicators, Rowland and Kuchel (2023) categorised them into three clusters: interested, appreciative audience; uninterested audience; and sceptical or polarised audience. The authors argue that for effective communication, science communicators must first identify their target audience to ensure the communication objectives are aligned with the audience. From this framework, science communicators in the environmental field can adapt their strategies to work with different types of audiences. For example, Taylor *et al.* (2022) emphasise the importance of engaging local communities to achieve successful biodiversity outcomes in urban areas. A systematic review conducted by Sextus, Hytten and Perry (2024) volunteers are indispensable to conservation, offering both a cost-effective labour force and a means of promoting environmental advocacy within their local communities. Regarding botanic gardens, the Communities in Nature project, conducted across various locations in the United Kingdom, demonstrated that these institutions can play an active role in engaging local communities while addressing both societal and environmental challenges (Vergou and Willison, 2016).

2.3.2 Roles of science communicators

The societal roles of science communication have been explored, with Davies (2021) providing a comprehensive review. The author identified 6 main roles for science communication, namely, 1. Accountability: scientists have a duty to communicate to the citizens to fulfil public trust and justify funding; 2. Pragmatic: science communication provides practical knowledge to individuals and policymakers, facilitating to researchers access to citizens needs and knowledge; 3. Enhancing democracy: science communication fosters public debate and equips citizens with critical thinking skills, essential for informed participation in democratic processes; 4. Cultural: science communication facilitates shared understandings, celebrating scientific achievements, providing enjoyment and educational enrichment, and shaping societal identities and values; 5. Promotional: science communication could be used for marketing or promotion, sometimes reducing science to institutional branding efforts that prioritise self-interest over critical engagement and reflexivity; and 6. Economic: science communication is crucial for attracting individuals to careers in science and preparing a workforce in technology-driven economies (Davies, 2001).

Understanding the distinct roles assigned to science communication inherently implies examining the roles of professionals in the field, including how they interpret, enact, and adapt these roles within diverse settings and contexts. Within this framework, Pielke (2007) conceptualised the role of a science communicators as a particular set of behaviours, responsibilities, and strategies that practitioners might adopt to interact with the public or policymakers. These roles encompass how science communicators choose to communicate their expertise, advise on decisions, and engage in the broader societal context. It also provides a framework to understand the practical and meaningful choices scientists or other actors make in their professional interactions with policy and politics. The author defined four roles in his research: 1. Pure Scientist, who provides information about science, leaving the decision-making entirely to the audience; 2. Science Arbiter, who acts as a resource to answer audience questions without guiding their preferences; 3. Issue Advocate, who might persuades the audience to adopt a particular opinion, thus limiting their choices by advocating for one or a few options; and 4. Honest Broker of Policy Alternatives, who provides comprehensive information on all relevant facts, enabling the audience to make an informed decision based on their own preferences and values (Pielke, 2007).

While Pielke has focused on scientists, other studies have been conducted to understand the roles of other actors in the science communication landscape. Fahy and Nisbet (2011) explored the roles of science journalists, creating nine clusters, namely, the conduit, who explains or translates scientific

information from experts to non-specialist audiences; the public intellectual, who synthesises complex information about science and its social implications, presenting it from a distinct perspective; the agenda-setter, who highlights important research, trends and issues; the watchdog, who scrutinises scientists, scientific institutions, industry and policy-orientated organisations; the investigative reporter, who conducts in-depth investigations into scientific topics; the civic educator, who informs non-specialist audiences about the methods, aims, limits and risks of scientific work; the curator, who organises and evaluates science-related news, opinions and commentaries; the convener, who facilitates science-based discussion between scientists and the publics; and the advocate, who reports with a specific worldview or on behalf of an issue or idea (Fahy and Nisbet, 2011). Based on the previous work, Jarreau (2015) identified that science bloggers perceive their roles mainly as explainers, public intellectuals, and civic educators.

Millani *et al.* (2021) conducted a study exploring the roles of various professionals engaged in science communication, such as freelancers, activists, designers, journalists, researchers, and communication officers. Drawing from Pielke's (2007) conceptual framework and categories identified by Fahy and Nisbet (2011) and previous research made by the authors, the study conceptualised roles as the specific ways in which science communicators engage with their audiences. Therefore, according to Millani *et al.* (2021, p.37), a science communicator 'adopts roles when they communicate' with the audience, and each role 'characterises the communication activities that connect' science communicators with their audiences. The authors identified six roles that science communicators adopt, namely the broker, who facilitates connection among diverse actors such as target audiences, scientists, and organisations; the listener, who strives to understand the audience better, integrating audience needs; the includer, who enhances accessibility and inclusivity; the enabler, who empowers audience to participate in science debates; the educator, who equips the audience with scientific tools, enhancing critical thinking; and the entertainer, who convey science through entertain (Millani *et al.* 2021).

Pielke (2007) focuses on scientists, positioning them within an ethical spectrum – from the impartial dissemination of information to more directed, advocacy-driven communication. His perspective is rooted in a traditional view of scientist as the primary actors in science-society interaction, holding significant control over decision-making in public communication. Fahy and Nisbet (2011) focus on science journalists, expanding the framework to include a sense of duty and public accountability. The authors acknowledge that journalists could play a role in societal critique and public empowerment towards science. Furthermore, it brings the perspective that science communicators could adopt multiple roles. The work conducted by Milani *et al.* (2021) contribute a further the spectrum of roles that science communicators adopt. The authors added audience-focused roles, e.g., listener. This

addresses a shift from communicator authority to active public engagement and empowerment, reflecting the move towards a more participatory model of science communication.

Together, the frameworks provided by the different authors reveal a complex and multifaceted landscape, within which the individuals engaged in these initiatives play a pivotal role in the functioning of society and the ways in which science and society can and do interact.

Table 1. Dimensions of the identified roles of science communicators. Each dimension encompasses a spectrum of goals. For example, the inform dimension may range from simply delivering information to tailoring that information to meet the specific needs of the audience. Furthermore, some roles may encompass more dimensions than those represented, but these are not their primary goals. For example, both the civic educator (Fahy and Nisbet, 2011) and educator (Milani *et al.*, 2021) roles involve the inform dimension, but this is not their core objective. The dimensions identified for each role are outlined in the models of science communication proposed by Bucchi and Trench (2021). Specifically, the dissemination model addresses the inform and educational dimensions; the dialogue model focuses the engage and, to some extent, advocacy; and the participatory model emphasises empowerment and, to a degree, advocacy.

AUTHOR(S)	ROLE	DIMENSION				
		Inform	**Educative**	**Engagement**	**Advocacy**	**Empowerment**
Pielke (2007)	Honest broker	✓	✓			✓
	Issue advocate				✓	
	Pure scientist	✓				
	Science arbiter	✓				
Fahy and Nisbet (2011)	Advocate				✓	
	Agenda-setter				✓	
	Civic educator		✓			✓
	Conduit	✓				
	Convener			✓		
	Curator	✓				
	Investigative reporter	✓		✓		
	Public intellectual			✓		✓
	Watchdog				✓	
Millani *et al.* (2021)	Broker			✓		✓
	Educator		✓			
	Enabler			✓		✓
	Entertainer			✓		
	Includer			✓		✓

Listener	✓	✓

The roles identified by the authors referenced in this literature review (**Table 1**) reflect the varying dimensions among science communication practitioners. The dimensions identified, namely inform, education, engagement, advocacy, and empowerment, represent the priorities of practitioners in relation to their desired outcomes for audiences. While other dimensions may exist, these are the most aligned with the scope and focus of the participants this thesis explores (botanic garden staff who engage in science communication). The works of Pielke (2007) and Fahy and Nisbet (2011) primarily focus on scientists and science journalist, respectively, and this thesis seeks to explore whether these roles are also reflected in botanic gardens.

As illustrated in **Table 1**, there are key differences regarding the dimensionality and audience interaction across the different authors. The roles identified by Pielke (2007) are primarily centred on the direct transmission of knowledge (inform), with minimal emphasis on audience engagement. Only one of his roles, the honest broker, incorporates multiple dimensions and is more audience centred. These roles reflect a more traditional, top-down model of communication, and may align with deficit model conceptualisations and those more oriented towards dissemination. Fahy and Nisbet (2011) introduce a broader variety of toles, each incorporating different dimensions. These cross a spectrum of framings of the science and society relationship including dialogue and participatory models of communication. Millani *et al.* (2021) present roles that place a stronger emphasis on audience involvement, particularly through empowerment and engagement, reflecting the shift towards more participatory and interactive models of science communication.

Some roles of public relations align closely with some of the roles of science communication. Both fields involve persuading and advocate for their respective domain, if we assume that science is viewed as the 'client-organisation'. For example, Hutton (1999) delineated six roles for public relations, namely, persuading audiences to think or act according to the benefit of the client-organisation; advocating for the client-organisation; education; crusader for citizens; information provider, and reputation manager of the client-organisation. These roles have similarities with the roles identified for science communicators. For example, public relations and science communication professionals both aim to educate their audiences, whether about a product or service in public relations or about scientific concepts and research findings in science communication.

2.3.3 Conceptualisation of science communicators between science-society interaction

Turnhout *et al.* (2013) and Milani *et al.* (2021) have investigated how science communicators perceive the relationship between science and society. The former developed a framework termed 'repertories' to analyse the scientists' conceptualisations linking knowledge production and use in their roles and practices. This framework identified three repertories - supplying, bridging and facilitating - each differing in their approach to maintaining distinct boundaries between science (knowledge production) and society (knowledge use). Building on this framework, the later study explored these repertories among diverse science communication professionals such as scientists, artist, communication officers, and blogger.

While science communicators may not explicitly state their views on the science-society relationship, their perspectives can often be inferred from their communication activities. Therefore, according to both studies, in the supplying repertory, science communicators provide knowledge or connect experts with knowledge users. While there is some interaction between knowledge producers (such as scientists) and users to understand which questions need answers, this interaction primarily serves the purpose of supplying desired information. This setup implies a one-way relationship from science to society, where information flows predominantly in one direction. In the bridging repertory there is an increased interaction between knowledge producers and users, with knowledge producers actively seeking input from users to inform the knowledge production process. Similar to the supplying repertory, there remains a linear relationship and distinction between science and society. However, the interaction allows society to influence and shape scientific endeavours. While in the facilitating repertory, science communicators seek an integration of knowledge production and use where knowledge users play an integral role in the production process rather than being merely consulted. All actors are recognised as having valuable knowledge to contribute, resulting in a scenario where science and society are integrated rather than perceived as separate entities.

2.3.4 Study framework for science communicators roles and conceptualisations

The roles of science communicators are diverse and integral to engaging society with scientific knowledge. Millani *et al.* (2021) elaborate on these roles, emphasising the multifaceted ways in which science communication operates across different professional contexts. The authors delineate six roles - broker, listener, includer, enabler, educator, and entertainer – which this thesis will explore. The examination of these roles underscores how professionals navigate in bridging scientific knowledge with societal context, providing a foundation for access within other science communication settings. The repertories identified by Turnhout *et al.* (2013) and Millani *et al.* (2021), namely supplying,

bridging, and facilitating form one of the empirical frameworks to assess how science communicators balance knowledge production and knowledge use.

These insights highlight the nuanced and evolving nature of science communication practices, setting the stage for a comparative exploration of how similar dynamics unfold within the context of different scientific institutions such as botanic gardens. I opted to rename the repertories as conceptualisations to enhance clarity for non-science communication scholars. This adjustment is particularly relevant for professionals in botanic gardens seeking insights into how they can effectively bridge science with society.

2.4 Summary

The theoretical framework of science communication has evolved to address various issues and solutions identified by its paradigms. Notably, public relation models intersect to some extent with the models of science communication, and some aspects from the practical component of science education overlap with those of science communication. Botanic gardens serve as hubs of science communication and although often perceived primarily as centres for science education, their staff is engaged in communication in a diverse array of activities, typically grounded in science communication models. Nevertheless, no study has yet provided a comprehensive account of the science communication activities and target audiences of botanic gardens, nor of the roles of science communicators within the context of botanic gardens.

Chapter 3

METHODOLOGY

This chapter outlines the research design for this thesis guided by the following two research questions:

> **RQ1:** 'How do botanic gardens reflect contemporary science communication practices?'
>
> **RQ2:** *'How do communicators working in Botanic Gardens embody science communication within distinct cultures?'*

3.1 Epistemological position

This research applied an approach based on critical realism to the research design elaboration and interpretation of results. Critical realism postulates that there is a reality independent of our knowledge or awareness and, as such, my analysis, as systematic and methodical as it may be, will have some shortcomings due to my inherent subjective positioning (Gorski, 2013). To mitigate as much as possible this issue in RQ1 and RQ2, I will draw on different data sources using a mixed methods approach, namely information reported directly (interviews and surveys) and indirectly (national reports) by botanic garden communicators.

3.2 Mixed methods

To answer **RQ1**, I draw on a mixed methods approach. This approach does not entail a simplistic use of both methods to collect the data but their integration to achieve the outcomes of the research study (Mertens, 2020). According to Creswell and Clark (2018), there are three primary typologies for conducting mixed research, namely explanatory sequential design, exploratory sequential design, and convergent design. The first typology is employed in studies where the initial phase is quantitative, followed by a subsequent qualitative phase aimed to explain or expand upon the results. The second typology pertains to research in which the first approach is qualitative, with a subsequent quantitative approach based on the qualitative findings. In the case of the third typology, convergent design, both quantitative and qualitative methods are conducted simultaneously to enable the comparison or combination of results.

An explanatory sequential design was employed, firstly adopting a quantitative approach to find and catalogue the types of activities and target audiences into a broad spectrum, at a European level, followed by a quantitative survey and qualitative semi-structured interviews, with a focus on two European countries as study models.

The quantitative content analysis was conducted drawing on a sample of national reports from European botanic gardens. An online survey was created based on this analysis and sent to the country representatives of European botanic gardens, to complement the information that may be missing in the national reports, as well as to assess the relevance of the different types of activities conducted by botanic gardens to their visitors and for each target audience. Qualitative semi-structured interviews were then conducted to further understand and deepen the range of science communication activities and target audiences.

3.2.1 Data collection

The data collection encompasses three sources: national reports, an online survey regarding European botanic gardens activities and audiences, and semi-structured interviews with communicators working in Botanic Gardens in the UK and Portugal. These two countries were chosen for pragmatic reasons: Portugal was chosen as this is my home country and I have experience and connections with botanic gardens in this country, additionally my PhD is funded by a Portuguese studentship. The UK was chosen as the country where my PhD studies are based and because it has a diverse range of botanic gardens from the world-renowned Kew Gardens to small specialist gardens such as Chelsea Physic gardens. Further, my supervisory team are based in the UK and Portugal giving additional expertise in these two contexts.

National reports

The national reports are documents compiled by the European Botanic Garden Consortium (EBGC). The EBGC was established in 1994 to plan Europe-wide initiatives for botanic gardens, especially within the context of implementation of the Convention on Biological Diversity and other European biodiversity policies and strategies. It brings together representatives of all botanic garden networks within EU member countries, plus Iceland, Norway, Serbia, Switzerland and the UK. These reports cover the majority of the more than 900 European botanic gardens. EBGC is convened by the Botanic Gardens Conservation International (BGCI). As the Consortium meets twice yearly the representative of each country network is usually required to submit two semi-annual reports that compile

information about the activities carried out by botanic gardens in their country. These documents comprise several sections covering diverse topics (e.g.: conservation and management actions), including activities relating to science communication. Given the number of participating country networks and the standardised information collected through these reports, these documents should provide a robust source of data on science communication activities within the context of European botanic gardens. A request was made to the BGCI in 2020 to access the European botanic gardens' national reports. Following a data sharing agreement, BGCI provided a total of 118 national reports, covering the previous three years (2017-2019) and 28 countries.

The data collection criteria included all communication or education activities that occurred outside formal educational qualifications and was aimed at public audiences. Activities aimed at botanic garden workers or peers (e.g., horticultural training or tour guide training) were excluded from the analysis. All non-expert audiences were included and categorised further where possible (e.g. students. All activities where communication occurs were considered, even those where the intent may not be specifically science communication. For example, activities such as music concerts and theatre performances present opportunities that bring citizens into the garden where they may encounter other communication content. In addition, activities undertaken outside the institution's physical setting were included in the study, as long as they were carried out by the botanic garden. Only written information in the national reports compiled by the country representatives was considered. The activities, audiences and mapping of activities to audiences was then explored further in the online survey.

Online survey

Based on the categories for both the types of communication or educational activities and target audiences that were identified through the content analysis of national reports, an online survey was developed (**Appendix B**) to probe and refine the range of activities offered by botanic gardens. Additionally, the survey investigated respondents' perceptions about the relevance of science communication activities and how well particular activities engage audiences at botanic gardens. The nature of the survey was primarily quantitative but embraced some qualitative elements through open-ended questions. The survey was designed in Qualtrics and was distributed by email between December 2022 and March 2023 to each European country representative to the EBGC (or alternate representative), listed on the EBGC 2022 contact list (N=29).

Semi-structured interviews

Semi-structured interviews facilitate an in-depth exploration of topics through a flexible and fluid structure, characterised by a reciprocal dialogue (Edwards and Holland, 2013). Furthermore, the nature of **RQ1** and **RQ2** require a method that allows for verbal, personal, and interactive engagement, which cannot be achieved through surveys, as it was anticipated there would be a wide variety of experience and perspectives amongst participants (Crano, Brewer and Lac, 2015).

Additionally, the flexible structure allows the order and wording of a question can be adapted to the interviewee responses and knowledge about the topic, allowing the researcher to probe and clarify as needed. The central theme and core questions are maintained to ensure an equivalent coverage across all interviews, addressing all the research goals (Gillham, 2005). These features are not found in structured or unstructured interviews. Foreseeing that the sample would not be homogeneous (i.e. informants will hold different levels of knowledge, adopt different engagement methodologies to reach their audiences, have different roles at their institutions and different academic backgrounds), the use of semi-structured interviews enabled me to tailor the questions for each interviewee. Thus, this instrument could be adapted to the individual's responses, while at the same time maintaining the research focus (Crano, Brewer and Lac, 2015).

Pre-pilot interviews were carried out to obtain critical comments on the interview content (question wording, focus, order, redundancy, or replacement) (Gillham, 2005). Three pre-pilot interviews were conducted with experienced communicators from botanic gardens who had relevant knowledge for the research topic. The pre-pilot interviews participants were selected through purposive sampling, where each participant belongs to a different country outside of the UK and Portugal (the study countries). The selected participants were contacted through email and the interviews occurred between June and July 2021. Pre-pilot surveys were carried out via the online platform Microsoft Teams. At the end of the interview, participants were asked to provide feedback on the interview content. Subsequently, their interview responses were analysed to assess whether the interview successfully achieved the intended objectives. The pre-pilot analysis is not included in the sample/results because the interviewees do not work in botanic gardens from the UK and Portugal. Participants in the pre-pilot interviews were provided with the interview framework (**Appendix B**), consent form, participant information sheet and privacy notice (**Appendix A**).

After the pre-pilot interviews, two pilot interviews were conducted with two initial participants from Portugal. These interviews were transcribed and analysed, and necessary adjustments (questions reframed) were made to refine the interview framework (**Appendix B**). Both interviews were included

in the sample/results and followed the protocol explained below. These interviewees were also provided with the interview framework, consent forms, participant information sheet and privacy notice (**Appendix A**).

Following the pre-pilot and pilot interviews, a cluster sampling approach was adopted to sample communicators working in botanic gardens from diverse institutional contexts. Invitations to participate in this study were sent to the institutional e-mails of 15 botanic gardens from the UK and 8 botanic gardens from Portugal. The e-mails sought two types of participants: a person who delivers science communication (works directly with the public), and a senior/head of the educational department (or similar). However, in the end, the interview participants were those identified by the respondents to the botanic garden's institutional email. This garnered 26 interviewees. Two final UK interviewees were recruited through a convenience approach, during the Botanical Garden Education Network Conference, 2023. This convenience approach was used because the desired sample (diversity of botanic gardens and number of participants) had not been achieved.

Before arranging the interviews, all participants were provided with the interview framework, consent form, participant information sheet, and privacy notice. The interviews were conducted using the online platforms Microsoft Teams (UK and Portugal) or Zoom (Portugal), with an average duration of 50 minutes. All interviews were audio recorded and transcribed, following the procedure described in the ethics section (**Section 2.4**). Interviews with the Portuguese participants were conducted first and in Portuguese. However, one participant asked to do the interview in English since the person is fluent in English. The interviews took place between July and November 2021. Subsequently, the U.K. interviews were conducted between April 2022 and February 2023, in English.

3.2.2 Data analysis

To answer **RQ 1,** a mixed-methods approach was used drawing on a quantitative content analysis of national reports, a quantitative analysis (descriptive statistics) of the survey and a qualitative content analysis of a section of the semi-structured interviews.

National reports

A quantitative content analysis was employed in this study to analyse the national reports, since the goal for this analysis was to systematically classify and quantify the information provided about types of activities and target audiences. In this study, I employed both deductive and inductive coding, since

the name given to the categories (types of activities and target audiences) already existed and were previously defined (for example, hands-on and general public) in most cases. However, in a few cases the code was inductively derived (for example, participatory activities).

A total of 118 national reports for the years 2017-19 were analysed from 28 European countries using a quantitative content analysis with a deductive approach for data codification and category development. The reports from the United Kingdom were excluded because they were not compiled by a botanic garden network, but by an external organisation that provides training and networking for the country gardens and gardeners (PlantNetwork, 2023).

Coding was approached as follows Thomas (2006): 1. Initial reading of sampled reports to become acquainted with and gain awareness of the content; 2. Rereading of sampled reports to take notes of key words, e.g., common words in reports – 'guided tours', 'concerts', 'workshops', 'lectures' (nature of activity), or 'schools', 'students' (audience); 3. Preliminary category development; 4. Rereading of sampled reports and testing of categories; 5. Development of categories; 6. Repetition of step 4 and 5; 7. Reduction of category number by merging related topics, e.g., 'print media' and 'broadcast media' merged into 'media', 'citizen science' and 'co-creation' merged in 'participatory activities', and 'physically disabled and wheelchair' and 'blind students' merged in 'underserved audiences'; 8. Rereading of sampled reports and testing of categories; 9. Adjustment of final categories; and 10. Final rereading and testing of final categories. The name of categories (codes) was created to group similar activities inside the same category. For example, participatory activities is a category that includes all reported activities with a participatory approach (e.g., citizen-science and co-creation).

Online survey

Despite the survey being designed with some qualitative elements (open-ended questions), none of the participants provided pertinent information. For example, when asked if there are any other types of target audiences, those who answered did not report new audiences. As a result, the survey was mainly quantitative, and Qualtrics software was used for descriptive statistical analysis of the data obtained from 19 responses, representing 19 countries, 17 of these were also represented in the national reports. The UK was not included as the EBGC representative is not from a botanic garden, for the same reasons as in the national reports.

Semi-structured interviews

A section of the 28 semi-structured interviews was analysed using a qualitative content analysis, combining a deductive (e.g., guided tours) and inductive (e.g., interpretation) approaches. First, I transcribed the interviews in their respective language (Portuguese and English). After, I carefully reviewed the transcription to become acquainted with the data. Subsequently, the transcripts underwent systematic coding; with the Portuguese codes being developed in English or joined with the English interview codes.

3.3 Thematic analysis

To address **RQ2**, the remaining questions of the 28 semi-structured interviews were analysed using thematic analysis according to guidelines produced by (Braun and Clarke, 2013), using inductive and deductive approaches. Thematic analysis is a technique used to generate, analyse, and understand patterns with qualitative data. It entails a systematic coding process to create themes, which constitutes the purpose of this type of method (Braun and Clarke, 2021). Thematic analysis offers various advantages such as flexibility for researchers to select their approach to data collection, theoretical positions, epistemological or ontological views; and it can be used to address a wide range of research questions and work with diverse types of data (Braun and Clarke, 2013).

The following process was followed: 1. the interviews were transcribed in their respective language; 2. they were carefully reviewed to allow familiarity with the data; and 3. the transcripts underwent systematic coding in English. After the codes were created, their meaning was interpreted to seek broad themes to address **RQ2**. For example, for the aims of communicators working in botanic gardens when they communicate with their audiences, codes emerged around curiosity, enthusiasm, and amazement. These were grouped as a theme with the name positive emotional outcomes. Another example regards the role communicators working in botanic gardens adopt towards their audiences, where the theme translator was derived from the codes language (accessible), intermediary, translator, and inform.

3.4 Ethics

For the national reports, a data supply agreement was designed by the Botanic Gardens Conversation International (BGCI). The terms and conditions were agreed and signed by BGCI and UWE in October 2020 (**Appendix A**). All national reports were delivered to my UWE student email by a BGCI officer and were subsequently stored on my UWE OneDrive, an online storage password protected platform. After data collection, all national reports were deleted. The results presented in this thesis did not disclose

the findings by country of origin to ensure confidentiality (e.g., specify what activities are presented in a certain country).

For the interviews and survey, all ethical elements were approved by UWE Health and Applied Science Faculty Research Ethics Committee. An ethics application for the thesis interviews was approved in May 2021, reference HAS.21.04.136. It included all the documents sent to the interview participants, namely interview framework (questions), consent form, participant information sheet, and privacy note. No sensitive or invasive questions were included in the interview. All data collection, analysis, and findings proceeded within the GDPR framework. In the context of participants anonymisation, a unique code was assigned to each participant. The audio recordings and transcriptions of the interviews were stored using these codes. After transcription, the audio recordings were deleted. Only a document containing the transcription codes along with corresponding participant details (name, organisation, and interview date) has been retained, and it will be deleted after all research articles from this thesis are published. All data have been stored on my UWE OneDrive (password protected). Regarding participants confidentiality, the results presented in this thesis do not contain any information that could lead to participant identification, such as given name, gender, detailed description of job function, or name of botanic gardens or plant-focused organisations studied in this thesis.

As a result of the analysis of the national reports, a need for further data arose. Therefore, an amendment to the previous ethics approval was requested to allow consent to conduct a survey. The amendment was approved in October 2022. Similar to the interviews, all survey participants were provided with a consent form, participant information sheet, and privacy note. The survey responses were stored in my UWE OneDrive (password protected). and deleted after data analysis. After all research articles from this thesis are published, the survey will be deleted from UWE Qualtrics (currently closed). To ensure participant confidentiality, none of the result from the survey reported information that could lead to participant identification. Namely, findings are not presented by country of origin (e.g., specify what activities are presented in a certain country), since there was only one participant per country.

3.5 Researcher positionality

Engaging in my self-reflection, there is no doubt that my previous professional experience as a research technician in ecology (before working in the educational service of a botanic garden), along with my academic background (biology) have influenced my scientific method. Another essential element to consider in this reflection is my experience working in a botanic garden, which has had the most

profound influence on my research. This factor permeated every stage of this thesis, due to my first-hand experience similar to the interview participants, as well as my knowledge about these institutions and their work. The way I have conducted the interviews and interpreted the data was shaped by it. I found that with many participants, establishing a quick connection was facilitated by a share sense of peer-hood, mutual understanding of 'botanic garden' language, or even some shared desperations related to the profession. Additionally, not every participant answered with clarity. My previous experience and knowledge in the field has been helpful in uncovering the nuanced and underlying meanings. I was particularly familiar with the Portuguese context, and more or less with two British botanic gardens, yet during the interviews, I deliberately acted as though I lacked prior knowledge about this context. This approach was taken to maintain reliability with the botanic gardens (BGs) whose realities I was not acquainted with. For instance, if a participant omitted to mention an activity that I was already aware of, I refrained from inquiring about it or including it in the results. I conducted the interviews with consistent knowledge and a consistent approach for all participants.

Chapter 4

CHARACTERISATION OF SCIENCE COMMUNICATION IN BOTANIC GARDENS

This chapter focuses on characterising science communication in botanic gardens with a view to addressing the first research question of this thesis:

> **RQ1:** *'How do botanic gardens reflect contemporary science communication practices?'*

It draws on data from the national reports of the EBGC (quantitative content analysis), surveys of the national representatives to the EBGC (descriptive statistics), and a section of the semi-structured interviews. It is divided into four sections:

> **Section 4.1.:** explores the types of science communication activities developed by European botanic gardens and the audiences they reach with these activities, using the national reports as the primary data source. It also explores the prevalence of the types of activities and audiences in the studied countries.
>
> **Section 4.2.:** building on the findings presented in section 4.1, this section investigates the range of activities offered by European botanic gardens and their audiences, using the survey as data source. It also explores the relevance of science communication activities and how well particular activities engage the audiences. It draws on the perceptions of the country representatives to the EBGC who responded to the survey request.
>
> **Section 4.3.:** examines and compares the types of science communication activities and audiences in British and Portuguese botanic gardens, using a section of the semi-structured interviews.
>
> **Section 4.4.:** provides a summary of this chapter.

4.1 Mapping and categorisation of science communication activities and target audiences

For the period 2017 to 2019, a total of 113 national reports were identified that met the study criteria, representing 27 countries (**Figure 1**). The number of reports per country varied between one and six.

Figure 1. European countries represented in the national reports: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, and Switzerland.

4.1.1 Science communication activities

A total of 1519 science communication activities were identified in the reports, grouped into 16 categories (**Table 2, Figure 2**), of which it was not possible to determine the type of activity in 66 cases (4.34%).

Table 2. Categorisation of the different activities identified in the EBGC reports, according to their description and goals. Categories were developed after the data were coded.

CATEGORY	ACTIVITIES	DESCRIPTION	GOAL
Arts	Music, theatre, performance, film exhibition, dance, song, installations, performances, animation, musical-botanical puppet show, songs dedicated to plants, art projects, floral stamps.	Visual or performing art forms (topics may be natured-based or not).	Display (activities whose main purpose is to show something visual to the public).
Asymmetrical communication activities	Workshops, stands, planner-meeting, asymmetrical network meeting (e.g., horticultural workers), face-to-face plant identification services, hobby groups, inquiry-based methodology.	Two-way communication activities with a (scientific) communication or educational purpose.	
Dialogue activities	Science cafés, round tables, consultations.	Two-way communication activities designed for mutual learning. The audience is an active generator of knowledge.	
Digital communication	Websites, podcasts, mobile apps, databases, social media profiles, virtual exhibitions, virtual reality/3D, computer games, web documentaries.	The content is delivered through a digital device. Excludes audio guides (which are included under the category interpretation).	Dissemination (one-way communication).

CATEGORY	ACTIVITIES	DESCRIPTION	GOAL
Events	Commemorative day, celebration, open day, thematic day, plant sales, plant fair, thematic plant fair, festival, researchers' night, markets, plant festival, demonstration, contests, cultural events, sports events, seed exchanges.	Events that are not art-based; it is not possible to know how the publics interact with the content.	Bring people to the garden; generate community; unknown.
Exhibitions	Exhibitions, plants display, plant exhibitions, unspecified exhibition, travel exhibition, animal exhibition, soil exhibition, touch exhibition, thematic exhibition, flower show.	All non-art-based exhibitions.	Display
Guided tours	Tours on-site or off-site.	Guided tours conducted by botanical garden staff or volunteers. These may take place inside or outside the botanic garden.	Interactive (activities where the public can ask questions).
Hands-on activities	Tree planting initiatives, practical activities, volunteer programmes, contests/competitions (when it is possible to know their nature), lab workshop, bookcrossing and flower crossing.	Practical activities.	Interactive (activities where the public can ask questions and participate actively).

CATEGORY	ACTIVITIES	DESCRIPTION	GOAL
Interpretation	Interpretation panels, interactive boards, labels, descriptions, braille signage, QR codes, signage, informative-educational boards, information panels, audio guides, marked/pre-defined paths and maps, audio information terminal, education tables, educational path.	Written and audio content, such as audio guides. Users need to be in a particular part of the garden to access the content.	Dissemination (one-way communication). The purpose is to facilitate interpretation of what visitors are seeing.
Media	TV, radio, documentary (TV), film (TV), interviews, newspaper, journal, articles, horticulture magazines.	Contents disseminated by media. Involves an intermediary, e.g., journalist, external to the garden.	Dissemination (one-way communication).
Merchandise	Stamps, calendars, catalogues, posters, plant products branding (e.g.: seeds).	Products created to be sold or offered as souvenirs. However, to be considered science communication tools, they need to deliver information to the public.	Dissemination (one-way communication).
Oral communication	Lectures, conferences, colloquia, masterclasses, classes, symposia, meetings, dissemination of knowledge, scientific consultancy, advisor/expert opinion, inform, information event, information day, results	One-way communication imparted orally.	Dissemination (one-way communication) or interactive (public can ask questions).

CATEGORY	ACTIVITIES	DESCRIPTION	GOAL
	presentation, seminars, presentations, communication campaign, talks.		
Participatory activities	Co-creation, citizen science, BioBlitz.	Activities where the public participate in their design, and/or data collection	Engagement (activities where the public is not viewed as a passive or active receiver of information, but an active provider or contributor of information).
Training	Training courses, course, online course, training sessions.	All types of non-formal training.	Interactive (public can ask questions).
Written communication	Brochures, books, posters, catalogues, booklets, maps, worksheets, leaflets, guidelines, templates, handouts, bulletins.	One-way communication imparted in writing.	Dissemination (one-way communication).
Other activities		The nature of the activity was unclear.	

The categories identified varied between 4 and 25 (**Figure 2**) in the studied countries. 'Exhibitions' was the most common category, being present in 25 of the 27 countries; contrasting with the category 'merchandise', which was reported by only four countries. 'Events' and 'oral communications' were the next the second and third more frequent categories, being reported in 22 and 20 countries, respectively. The 'interpretation' category was reported by 11 countries. Activities where citizens are viewed as knowledge holders and/or creators, namely the categories 'dialogue activities' and 'participatory activities', were reported in nine and 13 countries, respectively. Activities which rely on two-way communication, but in which citizens were viewed as passive receptors of knowledge - category 'asymmetrical communication activities' - were found in 19 countries. Activities about which it was not possible to determine their nature were widespread among countries and result from the nature of the reporting; they were placed within the broad category 'other activities', present in 20 countries.

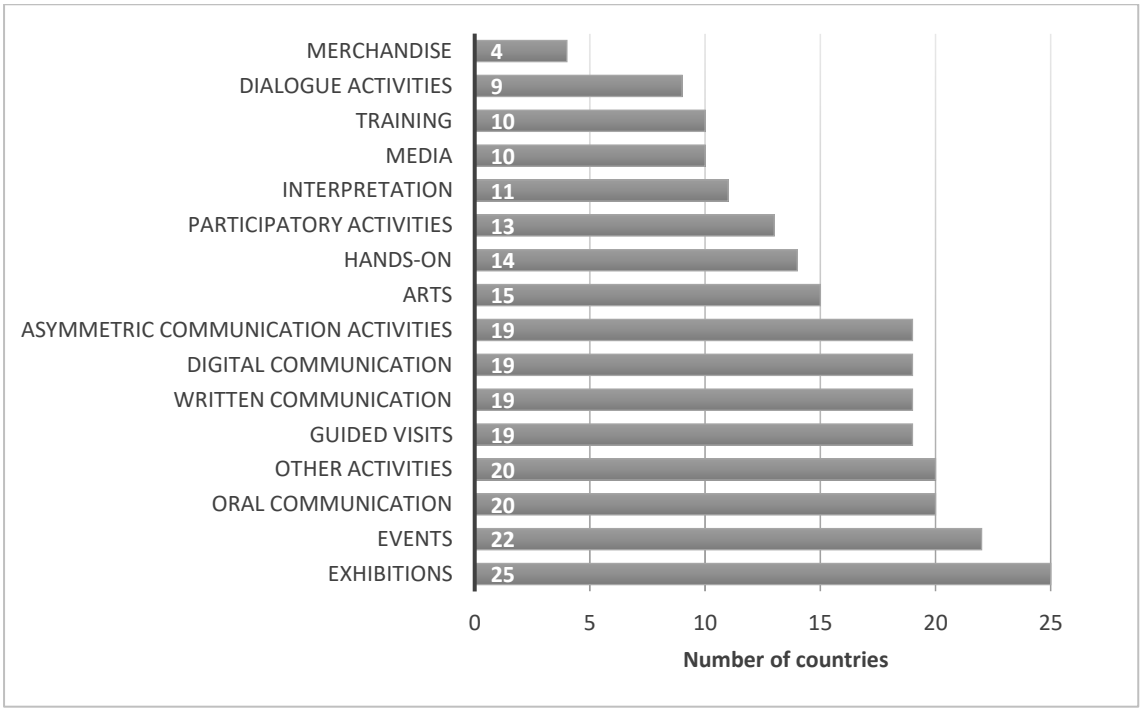

Figure 2. Number of countries (N=27) reporting each type of science communication activity identified in the national reports.

4.1.2 Audiences

From the 1519 science communication activities identified in the reports, the audiences were grouped into 18 categories (**Table 3, Figure 3**). However, of the 1519 activities, it was not possible to determine

the audience reached for 969 activities (63.8%). These categories emerged from the way that data were presented (**Table 3**, 'audience' column).

Table 3. Categorization of the different target audiences. The list of target audiences was retrieved from the EBGC reports and the audience categories were established following the codification of data.

CATEGORY	AUDIENCE
Adults	Adults of all ages.
Audiences with additional needs	Blind, physically disabled and wheelchair users, special educational needs, people with health conditions or impairments.
Children	Age is not given (children, kids).
Educators	School teachers, educators, school supervisors, lecturers, college teachers, university lecturers.
Families	All types of families.
General audience	Public is described as botanic garden general audience.
Other professionals	Non-plant/botany-related professionals.
Plant engaged groups	BG Volunteers, members of plant societies and associations, horticulture (students), Association of Students in Agricultural and Related Sciences, club members.
Plant specialised workers	Botanists, farmers, agronomists, plant breeders / producers, environmental workers, park workers, professionals of ecological engineering, etc.
Preschool	2–5-year-olds.
Primary school	6–11-year-olds
Secondary school	12–15-year-olds, 16–18-year-olds.
Seniors	Senior citizens, + 65-year-olds.

CATEGORY	AUDIENCE
Stakeholders	City authorities, customs officers, employees of Regional Directorates, governmental staff, environmental inspectors, social cooperative enterprise, environmental networks.
University students	Students from higher education.
Young adults	Teenagers, young adults.
Students	Unspecified educational status (school or university).
Not specified	Audience could not be determined or was not reported.

The identified categories varied between 2 and 27 among countries (**Figure 3**). Activities for which no audience was specified were common, appearing in all countries, and in all national reports, for instance it was reported guided tours without specify the audience. These are grouped under the category 'not specified'. For the activities that could be assigned to specific groups, 'general audience' was the most common audience, being present in 19 of the 27 sampled countries, while 'seniors' was only reported by two countries. Regarding the school panorama, students of unknown age – category 'students' - were reported by 18 countries. When students' age was given, 'primary school' was present in 10 countries, 'university students' in eight countries, 'secondary school' in seven countries, and 'preschool' in three countries. 'Educators' appeared in six countries as a target audience.

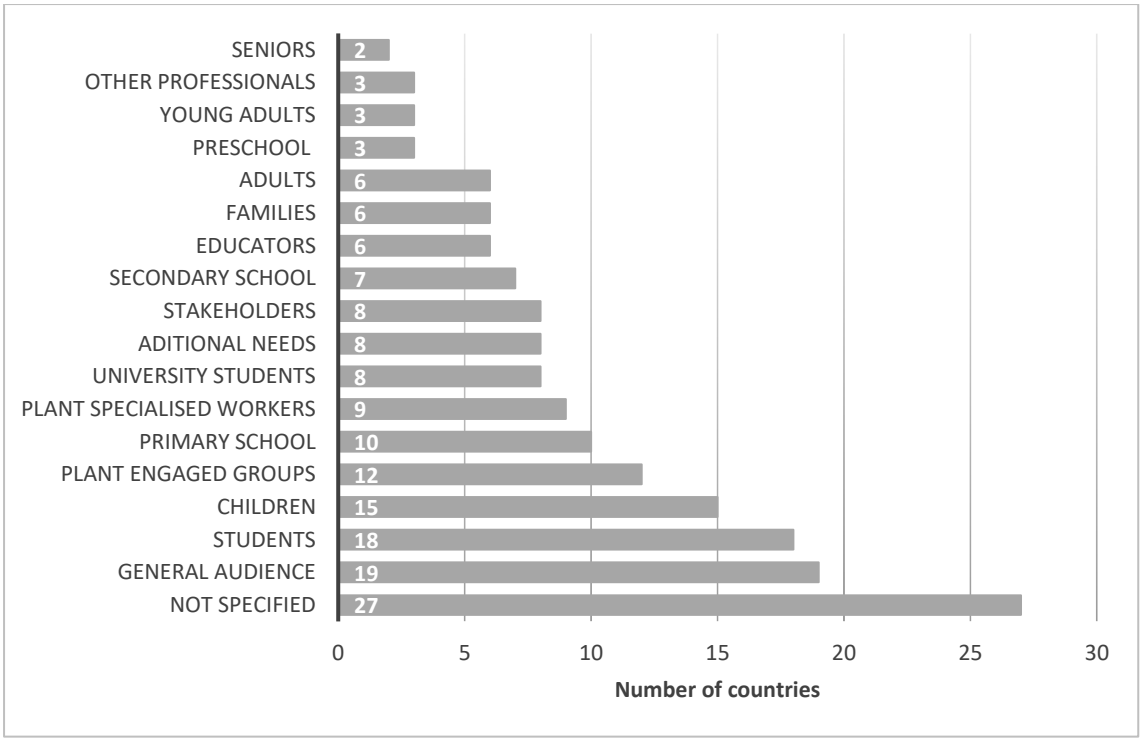

Figure 3. Number of countries (N=27) reporting each type of audience identified in the national reports.

4.2 Science communication: the European panorama

To further explore the data in the national reports, a survey (**Appendix B**) was carried out with the national representatives responsible for providing the national report data. This survey sought to complement the information that may be missing in the national reports, as well as to assess the relevance of the different types of activities conducted by botanic gardens to their visitors and for each target audience. The survey was distributed to 29 national representatives, of which 19 responded representing botanic garden networks in 19 countries (**Figure 4**). Two responses were received from countries where national reports were not previously available (see **Figure 4**).

Figure 4. European countries represented in the survey: Austria, Belgium, Croatia, Czech Republic, Denmark*, Estonia, Finland, Germany, Greece, Hungary, Iceland*, Ireland, Latvia, Lithuania, Netherlands, Poland, Slovenia, Spain, and Sweden. * Countries without available national reports.

Regarding the type of activities offered by botanic gardens to their audiences (**Figure 5**), all activities identified in the national reports were also reported by survey respondents. 'Arts', 'events', 'exhibitions', 'guided tours', and 'oral communications' are present in all surveyed countries, according to country representatives. On the other hand, fewer countries offered 'other discussion-based activities' (n=12) and 'participatory activities' (n=12) to garden visitors.

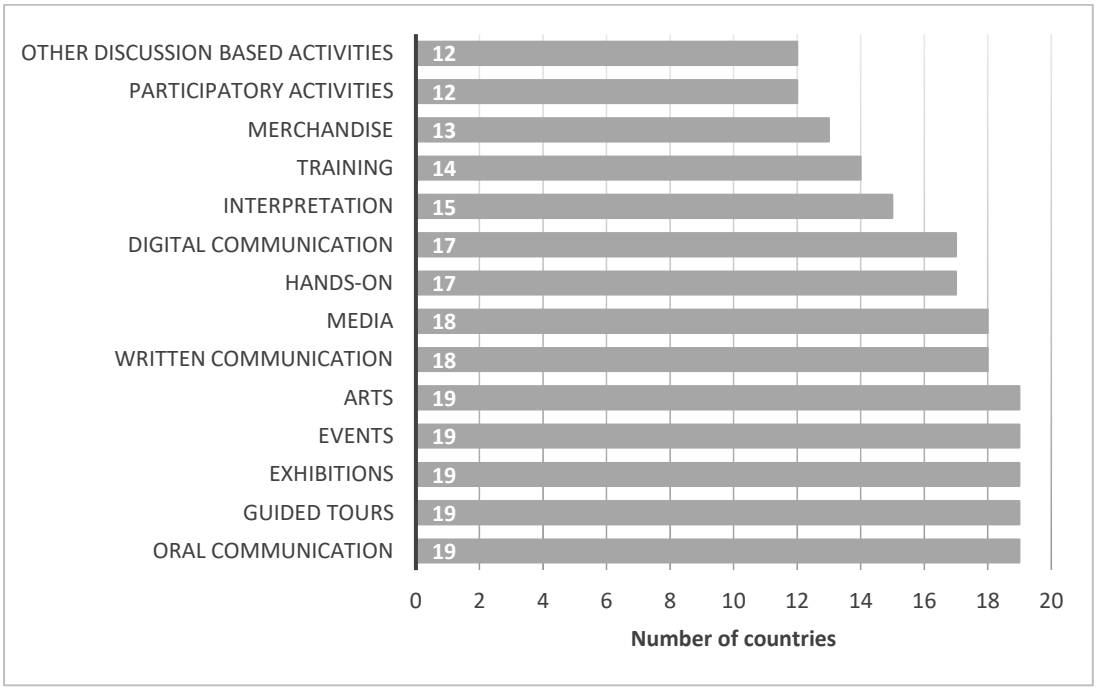

Figure 5. Science communication activities carried out by European botanic gardens. Each bar shows the number of countries which undertake each type of activity (N=19).

Concerning audiences, all country representatives (N=19) reported 'children', 'primary school', and 'secondary school' pupils as audiences, while 'other professionals' and 'stakeholders' were only specified by 8 and 10 of country representatives, respectively (**Figure 6**). As explained in the methodology chapter (**Section 3.2**), the categories students and non-specified audiences were not included in the survey.

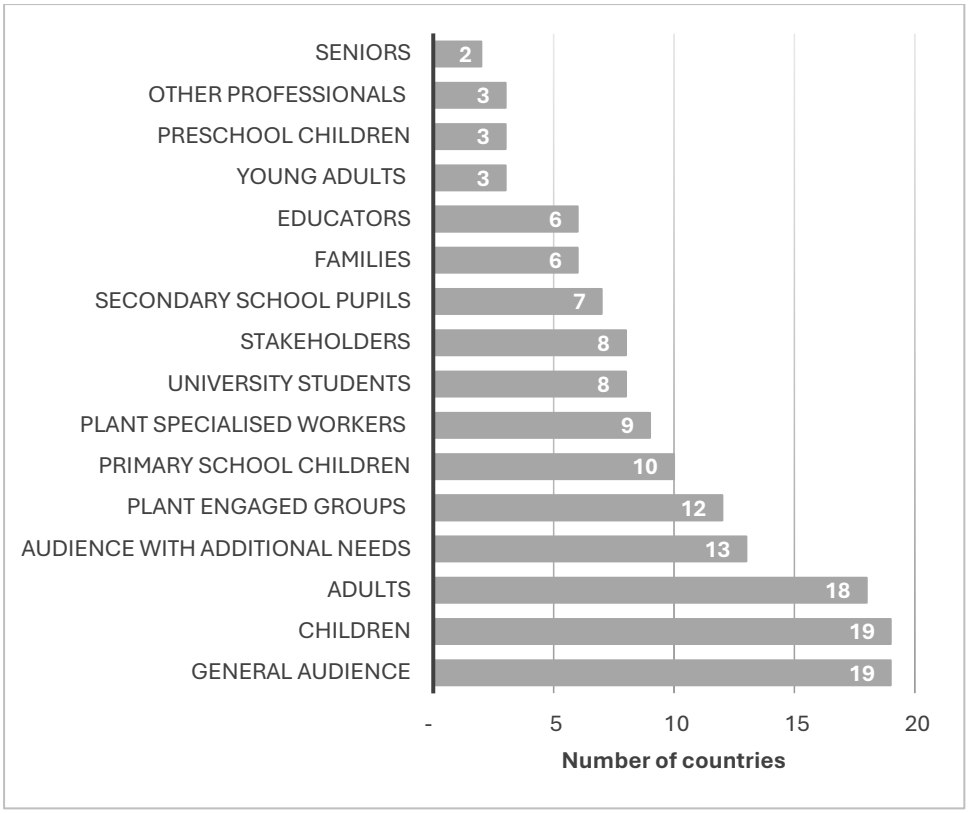

Figure 6. Audiences reached by European botanic gardens. Each bar shows the number of countries reporting activities aimed at the stated audience (N=19). Note: two respondents did not provide an answer for other professionals; and one respondent did not provide an answer for preschool children.

From the perspective of the country representatives (**Figure 7, Appendix B**) 'guided tours' and 'media' are the most important science communication activities for botanic gardens to offer to their publics, while merchandise and arts are seen as the less relevant.

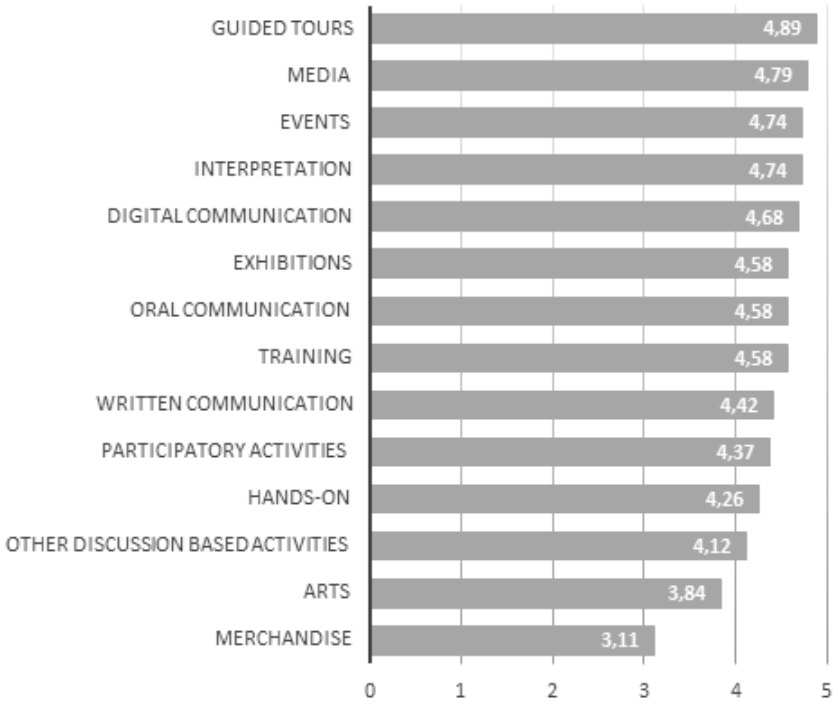

Figure 7. Perception of country representatives (N=19) as to the relevance of the different types of activities provided by botanic gardens, on a scale from 5=very relevant to 1=not relevant. Note: two respondents did not rate 'other discussion-based activities'.

According to the representatives of the European botanic gardens, certain activities are most suitable than others for involving each type of audience (**Table 4**). Not all categories of activities identified previously are viewed as the most appropriate for engaging audiences. For the audience 'adults', representatives showed greater alignment in their views, with 66.6 % (n=15) agreeing that art-based activities are the most suitable approach to engage this audience. Subsequently, 53.3 % (n=8) representatives agreed that 'families' are best engaged through 'events', while 'young adults' are best engaged through 'digital communication'. For the remaining audiences, no consensus was formed, since less than 50% of the representatives provided the same answer.

Table 4. Survey respondents were asked to identify which two activities are most effective at reaching each type of audience (N=15).

TARGET AUDIENCE	MOST EFECTIVE TYPES OF ACTIVITIES	PERCENTAGE
Adults	Arts	66.6%

	Exhibitions	26.6%
Additional needs	Guided tours	33.3%
	Exhibitions	26.6%
Children	Arts	33.3%
	Hands-on; digital communication; guided tours	20%
Families	Events	53.3%
	Exhibitions	40%
General audience	Guided tours	33.3%
	Exhibitions; media; events; digital communication	26.6%
Other professionals	Training	26.6%
	Written communication; oral communication; exhibitions	20%
Plant engaged groups	Exhibitions	33.3%
	Hands-on	26.6%
Plant specialized workers	Training	40%
	Hands-on	26.6%
Preschool	Events; hands-on	33.3%
Primary school	Hands-on	33.3%
	Participatory activities; guided tours; events	26.6%
Secondary school	Digital communication	40%
	Guided tours	26.6%
Seniors	Guided tours	33.3%
	Arts	26.6%

Stakeholders	Media	40%
	Interpretation	20%
Educators	Interpretation	40%
	Training; oral communication	26.6%
University students	Training; oral communication	40%
Young adults	Digital communication	53.3%
	Media	33.3%

4.3 Exploring science communication activities and audiences in UK and Portugal

The range of activities offered by botanic gardens and their audiences was further explored through interviews. This provided detailed information to enhance and elaborate the characterisation of the categories identified in the national reports. A qualitative content analysis was used for this purpose. The interviews were carried out between July 2021 and February 2023. In total, 28 interviews were conducted, 17 in the UK and 11 in Portugal, as described in **Section 3.2**.

4.3.1 Interview participants

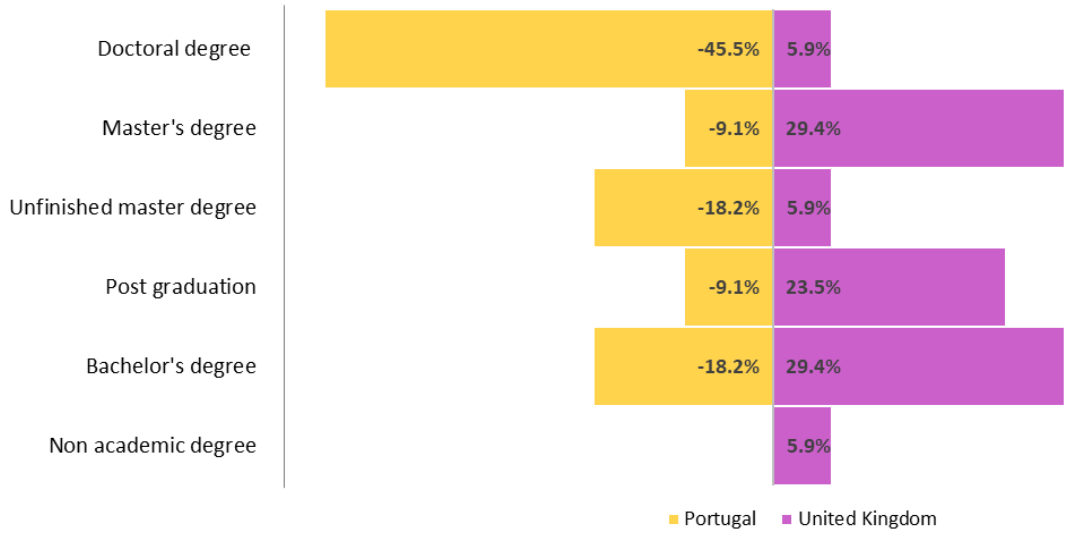

Figure 8. Highest educational attainments of communicators in botanic gardens (N=28). Portugal n=11; United Kingdom n=17.

The participants in this study are botanic garden staff who deliver activities or/and produce content for the public and/or manage the education/learning/communication team. This can be their primary or secondary job function. The educational profile of the participants from Portuguese and British botanic gardens is illustrated in **Figure 8**. Overall, from the 11 Portuguese participants, 5 had a doctoral degree. Amongst the 17 British participants, a master's or bachelor's degree (n=5) were most common. One participant in this study does not have an academic degree (UK). In order to maintain anonymity and confidentiality, the job function of the participants is not revealed. **Table 6** describes the areas of education of the participants. Most of the Portuguese participants have a nature-based science educational background, while British participants have diverse educational backgrounds.

The years of experience of study participants in the field of science communication (**Table 5**) ranged up to 35 in the UK and up to 25 in Portugal. This included all professional experiences that participants had outside of botanic garden settings, such as jobs in environmental public engagement, environmental education, or workplaces like sciences centres. For those who had previously worked as teachers, this experience was not considered.

Tabel 5. Years of experience of study participants in the field of science communication in the UK (N=17) and in Portugal (N=11).

Years of experience	United Kingdom		Portugal	
	N	%	*n*	%
Up to 5	5	29.4%	2	18.2 %
Up to 10	5	29.4 %	5	45.5 %
Up to 15	1	0.06 %	1	0.09 %
Up to 20	3	17.6 %	1	0.09 %
Up to 25	2	11.8 %	2	18.2 %
Up to 30	-		-	
Up to 35	1	0.06 %	-	

Table 6. Areas of education of communicators in botanic gardens (N=28). Portugal (PT) n=11; United Kingdom (UK) n=17. Note: Although there were 17 respondents from the UK, only 16 are included in the table, since one of them lacked an academic degree.

AREA OF EDUCATION	Bachelor				Post-graduation				Unfinished master				Master				Doctorate			
	PT		UK		PT		UK		PT		UK		PT		UK		PT		UK	
	n	%	N	%	n	%	n	%	N	%	N	%	n	%	n	%	n	%	n	%
Arts & humanities[1]	-	-	4	24%	-	-	-	-	-	-	-	-	-	-	2	12%	-	-	-	-
Education	1	9%	1	6%	-	-	6	35%	-	-	-	-	-	-	-	-	-	-	-	-
Nature-based sciences[2]	11	100%	5	29%	1	9%	-	-	1	9%	-	-	2	18%	3	18%	3	27%	1	6%
Other natural/exact sciences[3]	-	-	3	18%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Science communication	-	-	-	-	-	-	-	-	-	-	1	6%	-	-	-	-	-	-	-	-
Scientific dissemination	-	-	-	-	-	-	-	-	1	9%	-	-	-	-	-	-	1	9%	-	-
Social sciences[4]	-	-	3	18%	-	-	-	-	-	-	-	-	-	-	-	-	1	9%	-	-

[1] Arts & humanities: stage management and theatre practice; creative writing, English literature, and visual arts; Shakespeare and creativity; theatre performance; applied theatre; English literature.

[2] Nature-based sciences: biology; nature guides; management and conservation of nature; landscape architecture; forest engineer; ecology; education and sustainability; horticulture; botanical science; conservation; environmental sciences.

[3] Other natural/exact sciences: mathematics; chemistry; physical geography.

[4] Social sciences: environmental psychology; psychology; religious studies; politics and international relations.

4.3.2 Types of science communication activities

During the interviews, participants were asked to discuss the different science communication activities or practices they carried out, providing further details for some of them. Below a comprehensive overview of the findings identified during the analysis of transcripts is presented. It catalogues the types of science communication activities detected in botanic gardens in the UK and Portugal, along with the corresponding countries where they occur. Additionally, each category is accompanied by a description and/or examples, providing insights into the diverse approaches utilised within these settings.

ARTS AND PERFORMANCES

This category was previously designated as 'Arts' in the analysis of the national reports and surveys. However, based on the detailed information provided by the study participants, it has been renamed it as 'Arts and Performances', since the performances are a vehicle for knowledge dissemination. For example, Participant 3 (Portugal) described an annual ongoing activity in which botanic garden staff, including educational officer and gardeners, create diverse theatre scenes throughout the garden for the target audience to interact with. While Participant 2 (Portugal) explained:

> *I really enjoy performing and so what I did was to perform as a teacher in the 40's (1940's). So she was one of the most important, was the first woman doctorate, to have a PhD in botany in* [home country]*, (…) and she work in this museum that was the polytechnic school in* [home town] *in the 19th century (…). So she was working in the same building where I work, in the same botanical garden in the 30/40's more or less. So what I did was, I did a guided tour like I was her. I dressed like her, I studied her life, and then we called this a dramatized visit, where people came to know the different personalities that we want to give to their knowledge, so it was very good. I did another one in the museum (…) I think this is a great example of how to engage people, and I saw [something similar] at the botanic garden of Oxford, off course, I have this idea in the UK. I saw in the botanic garden of Oxford a visit that is not like this, you don't have an actor dressing like someone but you have, I don't remember the name, where they have an actor interviewing the guides. It is like a conversation between an actor and the guided, and this also works very well. So including theatre and drama in the activities and the visits you want to give it really works…'.*

Other examples given by participants fall into the following subcategories: art exhibitions, art demonstrations live streamed, theatre, music, other arts events. The staff of the botanic garden may or may not be involved in the event (e.g., theatre). The category 'Arts and performances' was identified in both countries and comprise a wide range of arts forms.

ASYMMETRICAL COMMUNICATION ACTIVTIES

This category, previously identified in the national reports, was subsequently merged with the category 'Dialogue activities' in the survey phase (**Section 3.2**). However, the analysis of the interview transcripts indicated that 'Dialogue activities' were not, in fact, presented at botanic gardens. The focus on activities described by participants is better described as asymmetrical communication activities. Therefore, retaining this classification is more accurate, as 'Other-based discussion' could led to misconceptions about the meaning, given that workshops fall under this category.

Workshops were widely reported in both countries; however, this subcategory has some level of ambiguity, as participants used the term 'workshop' to describe activities of various types. The intention is to distinguish hands-on activities, which are practical-based, from workshops, which are primarily conversation-based and include a practical component. In addition, science cafés were held in both countries and are included within the category asymmetrical communication activities. For example, Participant 2 (Portugal) mentioned hosting a series of science cafés and highlighted their relevance as strategy for public engagement:

> *'… we had the cycle of science cafes, … this is a very good methodology in terms of engaging people, because you can use researchers, real researchers. But instead of giving a talk, they are there in a café, in a coffee ambience so it's like, all of us are drinking a coffee and eating something, and they will answer the people's questions. So, of course it has to be moderated but it really works, it is an engaging methodology. You have to use, have to study engage methodology for the activities to work (…) The science cafes are a good example, you have scientists and you a mediator that should be a science communicator or a science educator, that is responsible for the dynamic of the activity …'.*

DIGITAL COMMUNICATION

The information provided by participants for this category was slightly less extensive than the data obtained in the national reports. Interviewees from both countries mentioned websites a vehicle to provide knowledge to the public. Additionally, Portuguese participants identified newsletters and social media as tools, while British respondents indicated they use podcasts, videos and online quizzes through phone apps.

EVENTS

The information provided by the participants did not add detail to this category, other than to offer an example of events as sleepovers. This category was identified in both countries.

EXHIBITIONS

The information provided by the participants did not add any detail to this category. It was reported the name of what the botanic garden offers to their visitors, such as plants shows and unspecified exhibitions. This category was identified in both countries.

HANDS-ON ACTIVITIES

This category was broadly mentioned by participants from both countries, where plant-based arts and crafts were frequently mentioned during the interviews. In addition, in both countries, participants mentioned games as hands-on activities; these were not found in the national reports.

INTERPRETATION

The information provided by the participants from both countries did not add any detail to this category, besides examples such as interpretative games, digital screens, and booklets.

MEDIA

The information provided by participants was considerably less extensive than that obtained from national reports. Only one interviewee in Portugal mentioned that the garden sends out press releases.

MERCHANDISE

This category was solely identified in the UK. For instance, Participant 12 (UK) shared information about a co-creation project to develop games about plants that are being sold at the botanic garden. While participant 15 (UK) reported:

> *'… and that is* [pollinators crisis] *led on to the gardens having a commercial arm where we are selling wildflower seed to people like the railway companies and water companies. So, when they do major works, they will use our wildflower seed to repopulate areas because in the past they would just buy generic seeds from Wilco or somewhere like that. So, these are things that should be in the area that are good for pollinators, and this is all been this interaction between our research work and public and industry…'.*

ORAL COMMUNICATION

In this category, participants from both countries mentioned in-person (UK, PT) and online (UK) talks for the public. Additionally, they referred to events that facilitate conversations between the visitors and scientists or experts. For instance, Participant 23 (UK) indicated *'…we do events where we bring the scientists, and they will do a kind of engagement with people as they come in and spend time in the garden …'*. While Participant 14 (UK) shared:

> *'… I would like to run sort of three-month programmes that would focus on one topic at a time, you know, like museums do exhibitions. I would want to do that, but on one thing so you could do a programme on evolution and that could include a debate with experts…'*.

PARTICIPATORY ACTIVITIES

In this category, participants shared information that facilitated a thorough characterisation of some participatory activities at botanic gardens.

<u>Citizen science</u>

The citizen science activities mentioned by participants in both countries tends to align with citizen science aimed at data collection rather than participatory formats, such as bioblitz, herbarium digitalisation, data collection, and wildlife monitoring. While citizen science is not a widespread activity

across botanic gardens, projects with a spectrum of passive and active engagement options were available for citizens. For instance, Participant 12 (UK) reported *'… They* [citizens] *are doing volunteering and doing transcription of digitization sheets, but you know, could be argued that is part of citizen science, but it's a bit passive…'*. Notwithstanding, there are citizen science projects that facilitate increased interaction between participants and scientists or botanic garden staff. For example, Participant 13 (UK) described an ongoing citizen science project that offers greater interaction for participants:

> *'… we're doing a piece of research actually in partnership with [name of the institution] where we are looking at the impact of biodiverse landscapes on your well-being. (…) we're working with a whole load of schools (…) and our general public. (…) they'll be given a little bit of information about the project, they'll then be hooked up to a heart rate monitor and a blood pressure monitor, and they'll be given a route to walk around the site. (…) a couple of hours later they will come back and we'll take that data and they'll fill in a kind of a form or so. So, we get some metrics around their anxiety levels, their enjoyment levels, that sort of thing. (…) the participant is basically a research subject. (…) we'll then talk to them about what has happened, what they felt and why various landscapes are better or worse for their well-being and things like that…'.*

Co-creation

This subcategory was identified in both countries. For instance, Participant 15 (UK) explained one approach that botanic gardens may use to facilitate co-creation with local communities:

> *'… so they* [target audience] *go out and work with community gardens and then they* [target audience] *do represent some of that work in the garden. (…) and recognizing their* [target audience] *expertise (…) more consultation and co creating things with the ethnic communities. (…) where people feel more represented in the garden and their cultures …'.*

Participant 12 (UK) shared an example of how a botanic garden can co-create with young people:

> *'…have you heard of Dragons Den? We run a Dragons Den (…) where they* [target audience] *come and they do a pitch to us and we feedback, they finalize their games (...) They write a design brief then we get them professionally developed through our creative services department, and then the young people have those games and they spend time coming* [to botanic garden] *to volunteer and stand in the temperate house*

to play the games with the public coming in. (…) not only the young people get a lot out of it, but also the public that engaged not only with the games but they engage with young people. (…) we also have a youth forum and through the youth forum we bring in facilitators for them to work out how they can develop activities to run with the public. (…) young people to be responsible, really to take leadership in what they are doing …'.

While Participant 2 (Portugal) explained about the use of co-creation as a strategy to reach and engage audiences who are nor regular visitors to the garden. Although not yet in practice, Participant 2 is currently developing a project within this framework:

'… the main question is for us now, who does not come to the garden, and those are people that I want to reach now (…) to create some groups [from audience segments who do not come] *and to ask them to think with me what we could do to offer activities that they like (…) co-created with them activities where they can help us (…) include them to teach to teenagers or children…'.*

Public consultation

Although interviewees may have confused public consultation with co-creation, I have analysed the transcripts focusing on their descriptions of the activities, rather than the terminology they used to refer to them. This type of activity was solely identified in the UK, where participants described the activity and it purpose. For instance, Participant 23 (UK) explained how public input shapes their botanic garden's activities: *'…what we want to do is do a lot of like community consultation with people, to find out like what do they want us to do. (…) we started doing like Pilates and Nordic walking and things 'cause people were looking for wellbeing activities…'*. While Participant 20 indicates how community knowledge could be helpful for a botanic garden:

'…the public can help us (…) sort of sourcing plants that we don't have, or sort of helping us to find rare plants, or if there are plants that say we're struggling to grow because we don't get the conditions quite right, say for example, if there's maybe a Jamaican person who lives in [the city], nearby, and they come to the gardens, they might possibly know how to grow the plant better than us, because obviously it's from where they're from as an example. So that's when they might possibly help us…'.

Others participatory activities

A participatory project, that does not fit under the above subcategories, namely citizen science, co-creation, and public consultation, was described by one British participant in this study. This project was developed by an institution in partnership with various botanic gardens (including the one that I interviewed) to address an issue concerning citizens: carbon footprint of food, aiming to change people behaviours, and intended for the local community. After, the results will be used to assess the effective engagement programmes in botanic gardens at promoting behaviours change. Participant 14 (UK) described this project as a:

> *'… collaborative project (…) that is looking at how effective can botanic gardens be at changing the behaviours of their visitors (…) carbon footprint of food which is complicated, the maths are horrid and you get lots of different opinions (…) we are trying to engage with 10,000 people over the next 12 weeks (…) giving them a little bit of information about the carbon footprint of their food, and an activity that helps them work out their own carbon footprint of their food, and an activity that helps them work out their own footprint (…) it's a family friend activity (…) we have taken all of the maths out of it, all that the public have to do is a tally chart (…) people turn up and we sort of explained to them that we have this challenge (…) will do day one together right now while you are at the garden, and then you take this activity home and you do it every day for two weeks (…) at the end of the two weeks, scan this QR code and send us data (…) prize draw, which is a nice little incentive …'.*

TOURS

This category was previously classified as 'Guided tours'; however, after analysing the interview transcripts, it was renamed as 'Tours' to more accurately represent what botanic gardens from both countries offer to their visitors. Although some of the interviewees used the name 'tour' and 'trail' interchangeably, others distinguished between guided tours and trails. The former refers to the tours around the garden usually led by a member of the staff. The latter typically follows a theme, where a booklet or prompt is provided for visitors to explore the garden. For example, Participant 13 (UK) explained *'… quite a lot of our programming is trail led. We have what we call* [name of the thematic trail]*, which are little packs that the kids can take and do lots of different activities around the gardens…'.* While Participant 2 (Portugal) mentioned *'… inquiry-based science education, we use this methodology, that thing that I told you of making people in a guided tour to have a question at the*

beginning and then they will collect clues along the trail, to come to the end and we make an answer. This is the inquiry-based science education …'.

TRAINING

This category was solely reported by UK participants, and the information provided did not add any new detail into this category.

VOLUNTEERING

Previously included as a subcategory of the category 'Hands-on activities', the information provided by participants added details that warranted its own category. The activities within this category are not exclusively hands-on, such as assisting with daily botanic garden operations, e.g., weeding. For instance, Participant 24 (UK) is a volunteer where his role is exclusively conducting guided tours. Participant 12 (UK) explained *'… young people have those games and then they spend time coming to [botanic garden] to volunteer and stand in the temperate house. To play the games with the public coming in…'*, while Participant 28 (UK) shared *'… we utilise education volunteers to deliver those sessions* [workshops]*…'*.

The volunteering could occur in different formats, as ongoing programmes or as on-off events, as for example Participant 12 (UK) reported *'… we have corporate days where we have volunteers come in and they might do weeding …*'. The same botanic garden can host both ongoing and on-off events. This category was identified in both countries, however, activities for volunteers beyond hands-on tasks were solely acknowledged in the UK.

WRITTEN COMMUNICATION

No participants reported activities under this category.

The participants reported a diverse array of activities, some of which are offered as ongoing services to visitors (e.g., guided tours), while others are offered occasionally (e.g., science café). Although not quantified, certain types of activities are prevalent across all sampled gardens from both countries, namely 'arts and performances', 'events', 'exhibitions', 'tours', 'hands-on activities' and workshops from the category 'asymmetrical communication activities.

The study participants illustrated the endeavours of botanic gardens to reach their audiences by: 1. incorporating interactive engagement, such as 'hands-on activities' and 'participatory activities'; 2. utilising multiple communication channels, from typical 'tours' and 'talks' to adopting platforms such 'social media' and 'podcasts'; and 3. integrating technology into their science communication activities, such as 'digital screens', 'online courses', and 'mobile phone-based activities'. This may reflect a growing recognition by botanic gardens of the need to employ multiple approaches in their outreach, engagement and communication activities to effectively reach diverse audience segments.

4.3.2 Audiences

To better understand how British and Portuguese botanic gardens cater for different audiences I explored the audiences they seek to reach with the science communication activities they provide. This was explored during the interviews, where specific questions were posed to the botanic garden staff regarding their audiences. Additionally, some of the audiences were identified during the interview outside the audience-orientated questions (see **Appendix B** for the complete interview schedule). As the types of audiences lack descriptions, unlike the types of activities, and all information was conveyed through the names of the categories or subcategories, I decided to organise the information into a table. Additionally, where necessary, I refined the categories identified in the national reports to better represent the reality of botanic gardens. Stakeholders, plant specialised workers, and other professionals were not reported in the interviews, probably the participants do not consider the interactions with them as science communication. Therefore, **Table 7** provides details on the different audiences mentioned by the participants, clustered into categories, each accompanied by examples where applicable.

Table 7. Audiences of botanical gardens, according to participants. The UK = 17 and Portugal =11.

AUDIENCE	COUNTRY	DESCRIPTION/EXAMPLES
Adults	UK; PT	older than 30; young adults 18-30 yr.
Audience with additional needs	UK; PT	Deaf community; cerebral palsy; association for people with additional needs. People with mental health issues; neurodiverse spectrum; disable groups or SEND groups.
Children	UK; PT	
Community	UK; PT	Local communities, e.g., local families, local schools, local ethnic communities. Specific community or group e.g.

		scouts, guides, brownies, friends' groups, retirement homes, hospital, theatres groups, dance groups. National and international communities, organisations, and associations.
Engaged people	UK; PT	Frequent visitors to the botanic garden. Frequently, the participants described them as white or older middle-class people.
Ethnic minorities	UK	
Families	UK; PT	Families with kids; families with older children; families with kids under 12 yr. old.; toddlers and parents/carers.
General public	UK; PT	
Non-engaged people	UK; PT	People who do not visit the botanic garden, e.g., university students, senior citizens, migrants, non-old white middle class.
Senior citizens	UK; PT	Retired people.
Specialist audiences	UK; PT	People with substantial knowledge of botany or other subjects.
Students	UK; PT	All ages, from nursery to university, local and nation-wide, including schools which do not often visit, schools in deprived areas.
Educators	UK	
University staff	UK	
Volunteers	UK; PT	General public, organisations, local university students, volunteers with expertise, people with an interest.
Vulnerable groups	UK	Deprived families, children, and people, including free school meal children, lonely people, socially excluded people. Also, low-income areas, foster care children with foster families, refugees, people from council housing.
Young people	UK	Youth local communities; youth communities across the country; teenagers.

All identified categories are present in the UK, and nearly all of them in Portugal; as 'ethnic minorities', 'vulnerable groups', and 'young people' were not mentioned in the interviews from Portugal. One of the reasons could be the variations in the ethnic diversity between countries, as some Portuguese participants expressed their intention to reach everyone in their local area. Another prominent finding in the results is that both countries engage with 'students', including 'young people', but only in the UK has the 'youth population' been explicitly mentioned as a target audience. This observation may

reflect the differing priorities of the countries regarding engagement or structural institutional affairs. Additionally, British participants identified 'educators' and 'university' staff as a target audience, which could also be influenced by country priorities, institutional matters, or cultural perspectives on science communication.

An observation that I made in the interviews was the fact that some participants from both countries specified everyone as their target audience rather than general public or others. This could indicate a lack of strategy in the development of the activities, since in one does not fit all, and without pre-defined audiences it may be harder to develop effective science communication activities.

Particularly in the UK, botanic garden staff identified their role in promoting social inclusion for diverse socio-economic and ethnic groups, as well as for people with additional needs. For example, Participant 19 (UK) said *'… we have a project to restore our glass houses and that focuses on all around diversifying audiences …'*, while Participant 23 (UK) explained *'…we focused on how to engage with underserved audiences, how to break down sort of barriers…'*. Additionally, efforts were noted by some participants to involve different local communities in the botanic gardens. For example, Participant 18 (UK) reported *'… we have priority audiences that are mostly children who live close by (…) we tried to engage those children most, and especially children who are receiving free school meals…'*; Participant 12 (UK) *'…we have horticultural allotments that run courses for community groups (…) we run community programmes that are on writing and on knitting [as a way to attract people to visit]…'*. Furthermore, a few interviewees have mentioned they work regularly with various organisations or association to increase the visits of vulnerable groups or local communities to the garden. As Participant 25 (UK) explained:

> *'… we go and hunt for funding to feed them because we know that if they come in on a free trip for the day that a lot of the families that access these activities (…) they probably won't get a really nice packed lunch put together before they come in, or there's a good chance and they can't afford to eat in the restaurant here (…) we use organisations like (…) they run family centres and the family centres are for families that are struggling financially (…) they'll lay on buses so the families will come…'.*

Therefore, study participants involved in enhancing the societal roles of botanic gardens have reported a range of approaches and audiences to promote these institutions as social inclusive places.

Participants from both countries indicated students and schools as their primary audience. For instance, Participant 4 specified 'schools' as the audience they aimed to reach, while Participant 22 (UK) stated *'…because that's* [schools] *our main audience…'*. Given that school visitors likely constitute

the group who most visit botanic gardens, ongoing activities for this audience are the basis for science communication in these institutions. Specially for the students who are not engaged in these subjects and do not may visit botanic gardens outside school events. UK participants reported programmes and strategies aimed to reach disadvantaged students or fostering families, for example.

4.4 Chapter summary

This chapter characterised the types of science communication activities and audiences at botanic gardens. In the national reports, representing the European landscape, I identified 14 categories of activities and 17 categories of audiences, derived through a quantitative content analysis. Following this, I refined these categories for the survey of European botanic gardens representatives to determine which activities and audiences are more common across Europe, as well as ascertaining views about their relevance for these institutions and public engagement. Finally, to ensure the robustness of these categories, I incorporated additional insights provided by the qualitative content analysis of the interviews I have conducted with British and Portuguese botanic garden staff. This resulted in the final framework of science communication activities and audiences at botanic gardens, as illustrated in **Figure 9.**, namely 15 categories for science communication activities, and 20 categories for audiences.

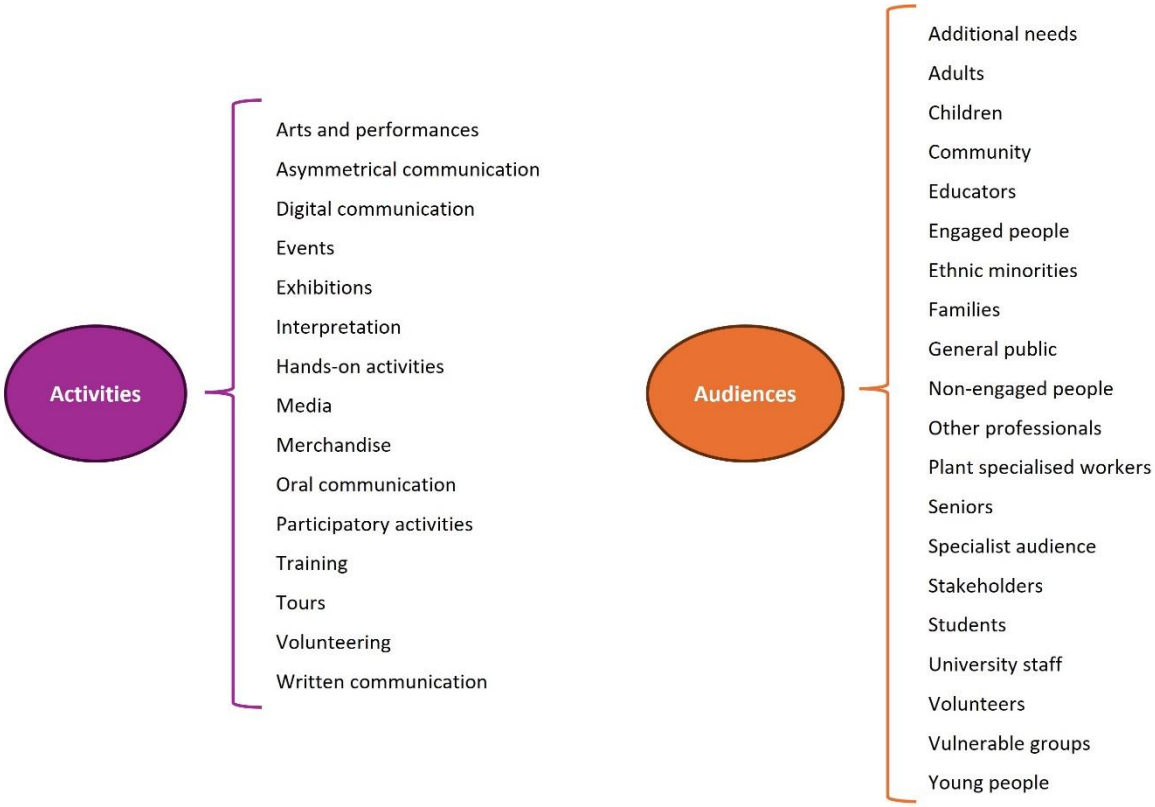

Figure 9. Framework for science communication activities and audiences at botanic gardens.

CHAPTER 5

CHARACTERISATION OF COMMUNICATORS WORKING IN BOTANIC GARDENS

This chapter focuses on understanding the communication practices of staff who engage in plant and associated science communication at botanic gardens, aiming to address the following research question of this thesis:

> **RQ2:** *'How do communicators working in botanic gardens embody science communication within distinct organisational cultures?'*

It draws on a thematic analysis of semi-structured interviews carried out between July 2021 and February 2023. In total, 28 interviews were conducted, with 17 in the UK and 11 in Portugal, as described in **Section 3.2**. This chapter is organised into five sections:

Section 5.1: explores the self-perception and understanding of science communication and science education among communicators in botanic gardens.

Section 5.2: investigates the aims that communicators have when communicating with their audiences.

Section 5.3: analyses the roles adopted by communicators towards their audiences.

Section 5.4: examines how communicators conceptualise the interaction between botanic gardens and society.

Section 5.5: provides a summary of the chapter.

5.1. Perceptions of science communication

Since anecdotal evidence suggests that science education is the main term used within botanic gardens, study participants were asked during interviews if they identified as science communicators or science educators. They were also prompted to share their thoughts on what the concepts of science communication and science education means to them. The analysis of interview transcripts

revealed that staff working in botanic gardens who engage in communication identified themselves as science communicators, science educators, or both. These identities were to some extent equally shared among participants and across both countries (**Table 8**). This may imply a balanced representation of communicators self-perception despite cultural contexts. Additionally, two new identities emerged during the interviews, namely discussant (Portugal) and facilitator (UK) (**Table 8**).

Table 8. Identities of communicators in botanic gardens. N=28 (UK N=17, Portugal N=11).

	Science communicator	**Science educator**	**Both**	**Discussant**	**Facilitator**
	N	*n*	*n*	*n*	*n*
United Kingdom	6	5	5	-	1
Portugal	4	3	3	1	-
Total	10	8	8	1	1

In total, eight study participants identified as **science educators**, with five of them having more than 20 years of experience in the field, and one having more than 10 years. Their educational backgrounds span various fields such as natural sciences, social sciences, education, and the arts. Although not valid for all cases, it is possible to discern a positive relationship between the identification as science educator and years of job experience. For **science communicators** and those identifying with **both** roles, there seems to be no association with educational background or years of job experience. Therefore, the identities participants perceived for themselves may be shaped by their individual conceptualisations of science communication and science education.

Different interpretations of these concepts were provided by participants, often centring on their understanding of the meaning of 'communication'. For instance, Participant 15 (UK) identified as a science communicator while Participant 19 (UK) as a science educator. Despite sharing similar views about their approach towards their audience, i.e., a two-way approach, they held **contrasting understandings** of science communication and education. Participant 15 (UK) stated *'… [I am a] communicator because **communication** is **two- way**. It shouldn't be [as an] me educator, sounds like I'm telling you. And communicator means we can have a communication about it…'*., whilst Participant 19 (UK) explained their role differently:

> *'… So, I wouldn't use the term science **communication** with my team, because I think externally it says that that it's kind of a **one-way** teaching experience in that somebody*

listens and they are communicated to, whereas an educator has a little bit more relationship with the audience member because education is about active involvement, whereas communicating I don't think. That language makes me not think it's active …'.

Moreover, there were participants who identified as science educators because they believe **science education encompasses a broader scope** than science communication. From their perspective, science communication is the dissemination of scientific knowledge to the public, and science education is a multifaceted process that goes beyond dissemination. For instance, Participant 27 (UK) who identified as a science educator, reported *'…* [I am an] *educator (…) communicate means explaining, but educating means explaining, understanding and learning…'*. Participant 12 (UK) also identified as an educator, explained:

'… [I am an] *educator, definitely rather than a communicator (…) you could see that science communication is about transmission of information, whereas educator is about including that, but it is much boarder and encourages people to do all the things that we were talking about earlier. You know, asking questions, thinking and getting to do, thinking skills …'*.

Other participants share the perspective that **science communication serves as a tool** for science education, for them science communication has an instrumental role. For instance, Participant 14 (UK), who identifies as science educator, considered *'… science communication is the method by which you achieve science education (…) so science education is what you want to achieve, and the way we have to do it is using science communication…'*, while Participant 8 (Portugal) stated*'…science education is the goal and science communication is the means* [to achieve it] *…'*. However, curiously, this participant identifies as a science communicator.

There were also contrasting views. Some participants believe **science communication encompasses a broader scope** than science education. As was explained by Participant 25 (UK), who identified as both:

'… I suppose, basically education is delivery of just delivery of knowledge and communication is putting that knowledge into a context that makes it relevant. So, science education could be reading a textbook and communication is what the teacher is supposed to do is to interpret the textbook in a way that makes sense…'.

While Participant 22 (UK), who also identifies as science communicator, stated:

> *'… I think education is tending to be a bit of a straight line and a bit more delivery and didactic, whereas communication is about understanding how people learn, and being able to manipulate subjects, activities so that those people can understand. Because I think communication expresses the ways that we learn better than the word education. Because education goes back in history as you sort of sit in a classroom, and there's a didactic nature about it, and whereas communication is more accessible (…) communication it's got to be broad, it can't be one-way (…) I think communications are not just about facts. It's about all the levels of things that others talking about, spirituality and emotional links and intellectual as well …'.*

Another rationale for identities was articulated by participants who did **not consider** there to be **a difference** between the two concepts; however, curiously, this does not mean that they share the same identities. Participant 3 (Portugal) mentioned *'… for me there is no difference between science communication and science education …'*, and therefore they identify as both. Participant 10 (Portugal), who identifies as a science communicator, started the answer with *'…I do not really differentiate between them now, but I used to … '*, but finished with *'… I see science communication as more free than education and formal learning (…) it is more informal both in terms of method and objectives (…) for me, they're not quite the same thing, but I don't even know if they shouldn't be the same thing…'*. Participant 28 (UK), who identifies as a science educator, provided information that could be somewhat contradictory within their identity, namely:

> *'… in a technical garden perspective, not for schools of course, but for a garden, I don't think there is a difference. I think people would think that science education, because it's the mediation more kind of formal. Communication could be more, is information someone delivered in kind of informal, that someone comes across in the garden. But I think it can be interchangeable. I think it depends on who's delivering it and who you're talking to …'*.

Although this participant initially stated there is no difference in a botanic garden context, later they described science communication as being more informal. Throughout the interview, this participant consistently referred to this type of job position in a botanic garden as environmental education, which may have potentially influenced the answer.

Some participants did not provide an exact conceptualisation, instead they based their understanding on how they **interact with the audience**. For instance, Participant 21 (UK), who identified as a science communicator said *'…* [I am a] *communicator (…) it is not necessarily my main job to educate (…) my main mission is to make it enjoyable…'*.

Notwithstanding, there were two participants who did not identify as either science communicators or educators. Participant 4 (Portugal), who identified as a **discussant**, stated *'… people are life philosophers (…) therefore all of us are intrinsic scientists (…) I support the idea that people should lose the fear of debate…'*. Participant 18 (UK), who identified as a **facilitator**, informed *'… I have never actually heard the term used that much as science communicator (…) I just call my self as workshop facilitator (…)* [because] *I am facilitating experiences…'*. The self-identifications of these two participants did not align with the two identities I provided during interviews. Neither of them has a markedly different education or professional background from the other participants; on the contrary, the discussant has a typical educational background (natural sciences) that can be found in botanic gardens, while the facilitator, although not typical, is not uncommon (arts & humanities). This may highlight broader perspectives on the way these two professionals see their job, as outside the education and communication rhetoric.

5.2 Communication aims

Through a thematic analysis of the interview transcripts, five communication aims were identified. Interviewees spoke about two types of communication between botanic garden staff and their audiences: direct (the communicators deliver the activity) and indirect (the communicator is not the person delivering the activity). Due to internet connection issues, it was not possible to identify the aims of one Portuguese interviewee.

5.2.1 Effective communication

Participants of this study reported that one of their primaries aims when they communicate with their audiences is to ensure an effective transmission of information. To achieve this aim, communicators need to improve the features of their communication by creating an accessible communication and developing audience-centred communication. This aim was identified in both countries.

<u>Accessible communication</u>

Participants seek to deliver their message effectively, emphasizing clarity and comprehension. Participants outlined the importance of using accessible language to ensure that audiences understand the information. For instance, Participant 8 (Portugal) pointed out *'…so they understand what I am saying…'* while Participant 27 (UK) emphasised the need for *'…clear, straight forward messages…'*.

Audience-centred

To respond to audiences' preferences and characteristics, participants tailor their communication to their audience. Participants expressed a desire to engage their audience by addressing their needs, interests, or who they are. For example, Participant 4 (Portugal) mentioned *'…something that is useful for them…'*; and Participant 13 (UK) stated *'…in any communications we always think audience first. Who is this particular piece of communication aimed at and why?...'*.

5.2.2 Facilitating learning

Interviewees want to enhance the knowledge of the audience. Participant 3 (Portugal) stated *'…I always want people to have a good time learning (…) they leave the activity satisfied and happy with the new knowledge they have acquired…'* while Participant 21 (UK) aimed *'…to make it educational…'*. Participants from both countries expressed this aim of imparting knowledge and facilitating learning experiences.

5.2.3 Create an engaging environment

Interviewees seek to create curiosity, enthusiasm, amazement, appreciation, and interaction in the audience. For example, participant 6 (Portugal) mentioned *'…first captative…'*, Participant 15 (UK) aimed *'…to get them excited about something…*', and Participant 18 (UK) goal was *'…to make everybody feel relaxed and comfortable in the environment to begin with…'*. Staff from botanic gardens from both countries shared this aim of appealing to and involving their audience in their communications.

5.2.4 Inspire

Interviewees aim to inspire their audiences and engage them with environmental issues, nature, or plant science, potentially leading to action or behaviour change. For example, Participant 8 (Portugal) mentioned *'…to pass to them the fascination for plants…'* and Participant 12 (UK) expressed a desire

to *'… encourage people to reflect and inquire about the topic, but also reflect on their own lives, so that they can consider how they might think more sustainably or live their lives more sustainably…'*. Participants from both countries have reported this aim, which emphasises motivation and fostering a sense of connection with the natural world.

5.2.5 Promoting botanic gardens

Interviewees aim to convey the importance of botanic gardens to their audiences. Participant 12 (UK) emphasised the significance of *'…deliver botanic garden mission…'* while Participant 25 (UK) aimed to *'… get the public to see the value of the BG as an institution and what it stands for…'*. This aim was identified only in the UK.

The themes suggest that interviewees shape their communication around three main orientations:

1. public-oriented - comprising communication that facilitates learning and engagement, is accessible and audience-centred communication.

2. environmental-orientated – comprising communication that seeks to inspire an interest in nature and may lead to behaviour change.

3. institution-orientated – comprising communication that promotes the importance of botanic gardens.

The public-oriented goals exhibited considerable diversity, revealing two distinct tendencies: the first tendency prioritises enhancing the visitor experience by fostering a strong connection with them, whether by addressing their needs or evoking emotional responses. The second tendency seeks to facilitate the audience's connection with content, either through translation or educational approaches. None of these tendencies are mutually exclusive, on the contrary, they could work synergistically. Furthermore, the vast majority of participants who mentioned engaging and/or learning as aims also emphasised effective communication. Notwithstanding this, the aims articulated by participants reflect an awareness and commitment to provide good practice in science communication, while fostering connections between their audience and plants, through incorporating public-orientated goals and environment-orientated goals.

In regard to the cultural context, out of the five observed aims, four were identified in both countries, with the aim of promoting botanic gardens only found in the UK. Interviewees articulated up to three different aims each. Among UK participants, the most common aim was engagement, followed by learning, with promoting botanic gardens being the least mentioned. Similarly, participants from Portugal most frequently cited engagement, followed by learning, while inspiration was mentioned the least.

5.3 Roles adopted towards audiences

The literature review (**Section 2**) discusses previous work on the roles adopted by science communicators in relation to the publics they seek to reach. A role differs from the aim of a science communicator because it refers to the specific goal that science communicators desire to achieve through their communication. It guides the overall purpose and direction of the communication, whether it is planned or not. On the other hand, a role indicates the actions science communicators take to connect with their audience. It shapes how they execute their communication, whether it is conscious or not. In summary, while an aim focuses on the overarching goals of communication, a role pertains to the specific action and/or behaviours that science communicators undertake towards their audience to achieve those aims. Milani *et al.* (2021) identified adopt six roles that science communicators adopt: namely broker, educator, entertainer, enabler, includer, and listener.

Thematic analysis of the interview transcripts identified seven roles adopted by interviewees towards their audiences, five of which were previously identified by Milani *et al*. (2021): broker, educator, entertainer, includer, and listener. However, two new roles were identified as pertinent to botanic garden staff: engager and translator. The enabler role identified by Milani et al. (2021) was not identified among the botanic garden staff interviewed. The following descriptions of the different roles are drawn from the interviews with botanic garden staff and adapted to the context of botanic gardens, providing evidence of how roles might play out in the specific context of botanic gardens and adding to our broader understanding of the roles that science communicators may adopt.

5.3.1 The broker

The broker acts as a bridge between audiences and other actors, such as scientists or experts, or between the botanic garden and their audiences and other organisations. The broker role includes science communicators that design activities to directly foster interactions between their audiences and a third party, e.g., scientist, horticulture experts, artists. These activities could be talks, speed

dating and workshops, among others. For example, Participant 11 (Portugal) described his role *'…was to create* [activity]*, I contacted people and invited them, and organised all… doing everything that is necessary [for the activity with the external actors to happen] …´*. Similarly, Participant 12 (UK) explained *'…we bring a game designer to talk to them [audience] about designing games (…) they have comedians (…) they meet scientists…'*; and Participant 13 (UK) narrated *'... so I create, I write the narrative and then I work with all of the artists to develop all of their different installations that are going to be part of that…'*.

The broker role could also apply to science communicators who collaborate with organisations or other intermediaries to reach specific audiences. For example, Participants 15 (UK) and 25 (UK) reported that they cooperate with associations that actively engage with their desired audience. In this context, the communicator is not creating specific activities, as the primary objective is to establish a means of reaching the audience. Instead, they create opportunities for the audience to interact with others (e.g. charities for low-income ethnic minorities). Additionally, intermediaries could be used to provide activities to the botanic garden. For example, Participant 14 (UK) states *'…we've got a collaborative project at the moment with [organisation] that is looking at how effective a botanic garden can be in changing the behaviour of their visitors…'*. These two aspects of the broker role are not mutually exclusively; some participants may assume one or both, depending on their job function and/or institutional scheme to reach particular audiences.

5.3.2 The educator

The educator seeks to create learning experiences with the audience. For example, Participant 21 (UK) said *'…so the first thing is what can we teach? the way I do it is - what we're going to teach them about? …'* Participant 26 (UK) also highlights the teaching role: *'…there are so many programmes here for me to teach …'*. Nevertheless, in addition to learning, Educators can strive to enhance the audience´s relationship with nature and environmental subjects. For example, Participant 23 (UK) explains the role of botanic garden staff as *'…this amazing role to play in looking at educating people about how you can protect the planet…'*.

5.3.3 The engager

The engager seeks to connect with the audience or connect the audience with the activity. For example, Participant 22 (UK) notes that *'…you need to be able to, I guess, manipulate things in such a way that the audience get an emotional attachment to what you're talking about at whatever level*

that might be to them…' and Participant 26 (UK) seeks to *'…help other people get enthused about it…'*. For the interviewee adopting this role, their primary action is to establish an emotional connection. If their goal is audience-orientated, they make use of their social skills to establish empathetic communication. Alternativity, if their objective is activity-orientated, they seek to evoke feelings of empathy or concern (depending on the subject) in the audience to foster a sense of belonging with the topic.

5.3.4 The entertainer

The entertainer engages the audience through entertainment. For example, Participant 7 (Portugal) explains *'…what I like more is the ones [activities] that have some dimension, the ones with a momentary creative dimension (…) the ones that have some theatricality, I am particularly seduced by theatricality …'*. While this role shares similarities with the engager role, participants in the entertainer role primarily focus on their activities rather than cultivating a sense of connection. Instead, they captivate the audience through engaging activities or by adapting their speech to provide moments of enjoyment and pleasure. Their main objective is to amuse and delight the audience, creating a positive experience for them. Not all participants in this role have a background in the arts. Participant 12 (UK) explores the link between entertainment and education, arguing:

> *'…it was edutainment right? Not education, not entertainment, but the two words put together to a made-up word of edutainment, which I didn't like that word, but it actually helps to understand that some of the things that you need to put on in a place like a Botanic Garden have to be entertaining…'*.

5.3.5 The includer

The includer seeks to make botanic gardens a place for everyone. For example, as Participant 12 (UK) explained *'…we're looking for those people who don't engage in nature or may face a barrier or don't think [the botanic garden] is for them…'*. Participant 26 (UK) goes on to say *'…we're currently trying to break those barriers of we're not just relevant to people who can afford to come…'*. This role can be passionately held, as Participant 27 (UK) articulates *'… to me that's very important (…) that we're looking and including everybody, and we have groups from every background, absolutely every background…'*. The participants who adopt this role are actively working to ensure that their workplace is inclusive and welcomes people from all backgrounds. They strive to break down barriers and make

botanic gardens accessible and relevant to everyone, regardless of socioeconomic status, ethnicity, knowledge level about plants, or any other factor.

5.3.6 The listener

The new role of listener seeks to understand the desires of the audience to include them in the activities. For example, Participant 20 (UK) stated *'…it's almost trying to let the teachers decide beforehand exactly what they want from us. And then obviously we need a little bit of information back from them just to be able to deliver it as well as we can…'*; and participant 23 (UK) *'…they [audience] were leading the activity in terms of looking at what they were most interested in…'*. The participants who adopt this role actively listen to the desires and needs of the audience so that they can tailor their activities accordingly. They prioritise input from the audience to ensure that activities meet their expectations. The listeners act through a collaborative approach.

5.3.7 The translator

The translator, another new role, acts as interpreter, informer and mediator between botanic gardens and society. For example, Participant 17 (UK) explained during the interview *'…who [science communicator] is all the time translating this information and going out and talking to people…'*. Participant 25 (UK) argues that the *'…prime role is to take the science that is done here and put it into a context and language that's accessible to anyone…'*. When assuming this role, botanic garden staff aspire to bridge the gap between scientific knowledge and public understanding by translating the complex information and concepts into accessible language and contexts for their audiences, with the goal of ensuring that those who engage with the activity leave with a thorough and clear understanding of the information shared. The educator and translator roles share similarities; however, the main difference between them is that the educator's primary focus towards their audience is to teach, facilitate learning, and promote understanding about nature/plants/environment. Whereas the translator's focus is to bridge the gap between science and society, by communicating scientific information in an accessible way.

All roles were identified in the interviews with practitioners from the UK and Portugal. Almost all participants adopted multiple roles, with only two participants (both from Portugal) adopting only a

single role (as translator) (**Table 9**). In the UK, the main roles indicated by participants included all except the broker, with engager and the educator the most frequent. Interestingly, in the UK all participants indicating that their main role is as an educator were found to adopt the translator as a secondary role, perhaps reflecting a pedagogical orientation. Also, in the UK, professionals who framed their main role as an engager, adopted educator as secondary role. Moreover, all interviewees whose main role was framed as a translator adopted engager as secondary role.

The Portuguese practitioners used language suggestive of only four primary roles: broker, engager, listener, and translator. The most common role identified was the translator, and there were no specific secondary roles associated with the translator role. Furthermore, the interviews indicate that the translator role is highly prevalent amongst Portuguese participants with all participants adopting this role as either their primary or secondary role.

Table 9. Roles adopted by botanic garden staff engaged in communication towards their audiences in the UK (N=17) and Portugal (N=11).

Role	*United Kingdom*		*Portugal*	
	Primary role	Secondary role	Primary role	Secondary role
	N	*N*	*N*	*N*
Broker	-	5	1	1
Educator	5	7	-	5
Engager	5	8	2	4
Entertainer	1	4	-	2
Includer	2	4	-	4
Listener	1	5	1	2
Translator	3	7	7	4

This analysis reveals a diverse array of roles adopted by botanic garden staff engaged in science communication, reflecting a complex interplay of responsibilities and approaches tailored to their audiences. The roles identified, including broker, educator, engager, entertainer, includer, listener, and translator, align closely with the established practices in science communication, underscoring the multifaceted nature of this field. The practice of science communication involves not only transmission

of information and promoting understanding of science but also foster connections and engagement, always considering audience needs. Regarding cultural context, roles were the feature of the practice of science communication where there was more evidence of its influence between participants from both countries. There is a clear difference between how participants act towards their audiences. Interestingly, the two participants who did not identify as science educators or communicators did not share their primary role with any other participant from their respective countries. The participant identifying as a discussant has listener as main role, while the participant who identifies as facilitator as entertainer as main role, uniquely holding this main role among all participants in both countries.

5.4 Conceptualisations of botanic gardens – society interactions

This section analyses how interviewees conceptualised the relationship between botanic gardens and society. Grounded in the work of Milani *et al.* (2021), who characterise repertory – in this thesis designated as conceptualisations - as the perspectives of science communicators regarding the interaction between science and society. Thus, I analysed their conceptualisations of the interplay between knowledge production (science) and knowledge use (society), and the types of communication activities that contribute to varying levels of this interplay. Additionally, I sought to understand how their conceptualisations are adapted to the context of botanic gardens. A communicator within these institutions is not typically a knowledge producer but could be framed as a scientific expert, occupying the same position as a knowledge producer in the interaction between knowledge producer and knowledge user. Understanding the conceptualisations of science communicators provides insight into how they approach the knowledge producer and knowledge user dynamics.

5.4.1 Supplying

The supplying conceptualisation is defined by a one-way communication approach, where knowledge delivery forms the base for conducting activities. Most of activities carried out by the participants in this study fall within this repertoire. For instance, Participant 19 (UK) when asked how the activities are planned, stated *'… I think about the audience first and then I'll be relevant research and I probably plan a program if it was over a period of time or think about it holistically, do the research, then plan it into kind of lesson format and then deliver it and evaluate …'*. While Participant 24 (UK) reported:

> *'… I can take a tour to any part of the garden, and to show and explain, and what the plants are in that part of the garden, so buildings as well (…) I might involve them with*

a bit of activity, now as we going around, we might stop to look at a particular plant and then I can explore perhaps that plant with the people, but with larger groups it's a bit more difficult to do that, but I do like to try and encourage participation from everybody …'.

For the same questions, Participant 2 (Portugal) answered:

' … for me the most important thing in terms of communication is engaging the public and you have some methodologies that help you to do that. You have to choose things that people feel that are integrated into their daily life, questions and well, mainly questions that people want to answer in their daily life because they are really interested in answering that for their own sake or whatever for the human sake. It is true because the best way to engage someone in plant conservation is for us to understand that we depend of plants for everything, for medical, pharmacy, clothes, furniture, materials, for everything, to breathe off course. And to do this I plan, we have programs that run during 3 months, they are divided in 3 months and we think about the things to maybe explore in each one, I think is a good idea to use this structure. I try to talk a lot with people, because that is the great advantage of planning and doing is that you get to talk a lot with people in your visits, in the visits I give, than I ask them what are their expectations, what they would like to know about plants for their one sake and for their own life, what themes they would like the garden to offer, and then you can systematise your work ... So I start with the things then I choose the activity, and the activity must be interactive wherever, even if you, I never give a traditional guided tour, you have to transform a guided tour into a question that everybody will answer during the tour in terms of collecting some evidences during the tour, picking from the ground, for instance, some plants, smelling, learning, trying to understand why that it is important to their question, and at the end of the tour they will be able to answer the question we had at the beginning (…), and then it really works because people were expecting this, so this is an example that you have to have in account, what people like, you as a botanic garden to offer, and this is very important…'.

The data I used to infer how participants conceptualise the relationship between botanic gardens and society was not solely drawn from the interview question 'how do you plan your communication activities', but also from other questions such as the ones related to the types of activities they conducted, the description of activities and different ways that the public can interact. I used these

quotes to illustrate that whether participants solely conduct tours, create interactive and engaging activities, or seek feedback from the audience, the core purpose of those activities is to supply the audience with knowledge. However, this does not mean that each participant has only one conceptualisation (for example participant 2 (Portugal) has supply and co-creation). Nevertheless, the supply conceptualisation is by far the most common and shared among all study participants.

In addition, although not quantified, tours are the most widespread activity in botanic gardens. Yet no interviewee reported giving tours or other common activities found in botanic gardens, such as events, workshops, hands-on, and talks, where the interaction between the knowledge producer or expert and the knowledge user may not unidirectional.

The participants described two tendencies within the supplying conceptualisation, which are not mutually exclusive. The first relates to the dissemination model of science communication, where the interaction strictly involves supplying knowledge through a one-way communication approach. For instance, Participant 5 (Portugal) explained:

> *'… we no longer do the planning of the tours because we already have the script done; it is just followed. In the begging we had to plan, study the botanical collections of the botanic garden, search for information about species, and learn how to translate that for lay people. In the begging it was trial error approach until we got suitable language to engage, capture people and make them understand what we are transmitting…'.*

The second tendency also employs a dissemination of knowledge approach but incorporates an asymmetrical two-way communication. In this approach, communicators pose questions and/or set out topics to foster conversation with and among participants, who are often invited to share their own knowledge about the topic. However, this interaction is not substantial enough to be considered a truly collaborative or participatory conceptualisation that would adopt a two-way communication. For example, Participant 3 (Portugal) mentioned:

> *'…To me it is essential to awaken curiosity in the audience, and for it to be an interactive and sharing moment* [among audience and study participants] *(…) I always want the audience to have a good time learning, in a very light, lively way, and to leave the activity satisfied and happy with the knowledge they have acquired (…) They can look for nature with new eyes, I even always talk about not looking at nature as green, and understanding what is there in that green, what is good, what is bad, or why it is there, why it exists, and without a doubt that they look at it with new eyes, and a greater curiosity, …'.*

5.4.2 Collaborative

The collaborative conceptualisation is characterised by a knowledge interaction and exchange, where the producers gather information from the users to shape knowledge production. Such activities remain primarily unidirectional, as producers primarily aim to harvest information that could be useful for them.

There are two levels of interaction within this conceptualisation concerning audience interactions. Citizen science activities serve as an example to illustrate these two these two levels. On the one hand, there is a level of interaction characterised by minimal dynamics, where citizens solely provide data to the botanic garden without a reciprocal exchange between both parties. The audience is largely passive in this interaction, receiving instructions on how to collect data without engaging in dialogue with the experts. For instance, activities such as herbarium digitalisations or transcriptions. Conversely, another level involves a higher degree of citizen involvement, thereby fostering increased interaction between them and the scientific experts. For example, citizens as research study participants, where there is a dialogue with the experts that provides mutual feedback. For example, Participant 13 (UK) described an ongoing citizen science project that offers greater interaction for participants:

> *'… we're doing a piece of research actually in partnership with [name of the institution] where we are looking at the impact of biodiverse landscapes on your well-being. (…) we're working with a whole load of schools (…) and our general public. (…) they'll be given a little bit of information about the project, they'll then be hooked up to a heart rate monitor and a blood pressure monitor, and they'll be given a route to walk around the site. (…) a couple of hours later they will come back and we'll take that data and they'll fill in a kind of a form or so. So, we get some metrics around their anxiety levels, their enjoyment levels, that sort of thing. (…) the participant is basically a research subject. (…) we'll then talk to them about what has happened, what they felt and why various landscapes are better or worse for their well-being and things like that…'.*

5.4.3. Participatory

The participatory conceptualisation is defined by all types of knowledge, including that produced by both experts and users, as well as scientific and traditional knowledge, should be integrated rather than relying on a single knowledge authority. While this conceptualisation may hold different

implications for research centres (scientist), within the context of botanic gardens the communicators may be as experts. This approach occurs although not frequently.

Like the preceding repertoire, there are two levels within the participatory regime. Public consultation activities exemplify an approach where the members of the public provide their knowledge, and it is integrated in the outcome. For example, to improve interpretation panels of botanic gardens, the local community (among others) is invited to give their views and feedback as Participant 15 (UK) explained:

> *'… so basically, we spent the last year probably. I am reviewing what we already were doing, speaking to staff, volunteers, students and communities, and other organizations. Writing a massive report, looking at all of the stories that would be told, through the herbarium about plant collectors. So a massive review of things. So now we've got this big review and report and action points. And we're gonna be hosting some community groups to come in to start, really, tackling some of it and getting their opinion and starting to make those changes …'*

Another example provided focused on how members of the public could provide horticultural knowledge about plants from their home country or ethnic heritage as mentioned by Participant 20 (UK):

'… If there are plants that say we're struggling to grow because we don't get the conditions quite right, say for example I'm picking at random saying Jamaica for example, just randomly off my top of my head. If there's maybe a [country] *person who lives in […] the nearby area and they come to the gardens, they might possibly know how to grow the plant better than us, because obviously it's from where they're from. .. So that's when they might possibly help us (…) with the Commonwealth Games that sort of happened over the summer in* [botanic garden city] *that we sort of did a Commonwealth Games project where we tried to grow the national flower of every Commonwealth country and the national and the national crop of every Commonwealth country (…). Some of them we already had at the gardens but obviously we didn't have them all (..). Our gardeners trying to source as many of these plants as they could (…) were then trying to contact like local community groups, for example again Jamaica as example, if they couldn't get the plant from Jamaica (…) we'd contact them to say we're struggling to get this plant. Do any of you have it or do you know how to get it or where to get it from?'*

On the other hand, Participant 2 (Portugal) described a deeply participatory approach that would put in practice a co-creation method to reach specific audiences. The goal is to engage audiences that are not currently visiting the garden by seeking co-creation with community members of each target

audience. This approach differs from the collaborative repertoire because the interviewee expressed a desire to integrate community members (the target audiences) as equal partners in the co-creation process. As Participant 2 (Portugal) mentioned:

> *'… the main question is for us now, who does not come to the garden, and those are people that I want to reach now (…) to create some groups* [from audience segments who do not come] *and to ask them to think with me what we could do to offer activities that they like (…) co-created with them activities where they can help us (…) include them to teach to teenagers or children…'.*

Three conceptualisations to mediate the interaction between botanic gardens and society were identified in participants from both countries. The **supplying** approach is by far the most common, both in terms of the variety of activities and the number of participants. This conceptualisation focuses on one-way dissemination of knowledge from the producer/expert to the user. However, even when the interaction between the communicator and the public involves an asymmetrical two-way communication, knowledge from the audience is not incorporated into the botanic garden, and it thus remains a supplying conceptualisation of the science-society relationship. The **collaborative** approach introduces a two-way exchange of knowledge, though the communicator remains the authority. Within this conceptualisation communication between the botanic gardens staff and their audiences could be one-way or two-way. This conceptualisation was observed in both countries, but it is more common in the UK than in Portugal. The **participatory** approach seeks to close the gap between botanic gardens and society. Within this conceptualisation, communicators advocate for the integration of the user's knowledge, using a two-way communication approach. It was identified in both countries, but as before, is more widespread in the UK. Therefore, the study found that the conceptualisations of communicators illustrate the full spectrum of conceptualisations of the science-society relationship, from strictly knowledge delivery to active involvement and empowerment of the audience.

5.5 Chapter summary

This chapter presents the results addressing RQ2, which explores how botanic garden staff engaged in communication embody science communication, as well as the cultural influence on participants from

the UK and Portugal. A thematic analysis was conducted with 28 participants, including 17 from the UK and 11 from Portugal.

Firstly, I investigated how participants perceive themselves in the field of science communication. No relevant evidence was observed between countries in the identities of science communicator, science educator or those who identified with both roles. Similarly, there were no notable differences observed between participants from different countries, suggesting that cultural influences do not impact their perceptions. Additionally, the participants profile data, namely educational background and years of experience, did not reveal any clear pattern, except among science educators who tented to have more years of experience compared to other participants. Two new identities were proposed by participants, namely discussant and facilitator. Regarding the conceptualisation of science communication, especially participants who identify as science educators tend to have a somewhat reductive view of this field.

Secondly, I examined the aims of study participants when communicating with their audiences. Five aims were identified: effective communication, engage, facilitate learning, inspire, and promote botanic gardens. Create engaging and facilitating learning were the most mentioned aims among participants from both countries, suggesting minimal influence of the cultural context. However, promoting botanic gardens as an aim was solely identified in the UK.

Thirdly, I explored the roles adopted by study participants towards their audiences. Seven roles were identified: the broker, the educator, the engager, the entertainer, the includer, the listener, and the translator. The engager and the translator are new roles identified for practitioners of science communication in botanic gardens. Cultural influences were observed, as differences were noted between countries. Participants from UK tended to adopt the engager or educator as main role, whereas participants from Portugal leaned towards the translator role, which may suggest different perceptions of what it means to be a science communicator.

Lastly, three conceptualisations between botanic gardens and society were identified: supply, collaboration, and co-creation. Supply is by far the most common in both countries. Collaboration was solely recognised in the UK. Co-creation was identified in both countries.

Chapter 6

DISCUSSION

Botanic gardens serve as public spaces where science communication about plants and associated sciences is offered to visitors. Given the declining interaction between humans and nature (Soga and Gaston, 2016), these institutions play a key role in fostering connections between people and plants. Therefore, it is important to understand the role of these organisations as active participants in the interaction between science and society. Furthermore, examining science communication across different countries provides a broader perspective on the nuances of geographic context, thereby enriching and expanding the insights.

In this regard, this chapter aims to provide critical interpretation and examine the implications of the findings of this thesis, addressing the following research questions:

> **RQ1:** *'How do botanic gardens reflect contemporary science communication practices?'*
>
> **RQ2:** *'How do communicators working in botanic gardens embody science communication within distinct cultures?'*

It is organised into 3 sections:

Section 6.1: Connecting people with plants: insights from European botanic gardens. This section aims discusses the categorisation of science communication activities and audiences as outlined in the national reports and surveys. Furthermore, it examines the insights provided by representatives of European botanic gardens regarding the relevance of science communication activities within their institutions.

Section 6.2: Connecting people with plants: practices in British and Portuguese botanic gardens. This section intents provides a comprehensive examination of the science communication practices in both countries, encompassing the types of activities offered and audiences addressed by botanic gardens.

Section 6.3: Science communicators within the context of botanic gardens: perspectives from the United Kingdom and Portugal. This section discusses how communicators working in botanic gardens

which have distinct cultures perceive their position as science communicators; their aims during communication activities; the roles they adopt towards their audiences; and their conceptualisations of the interaction between botanic gardens and society.

6.1 Connecting people with plants: insights from European botanic gardens

In this section, I aim to address aspects of RQ1:

'How do botanic gardens reflect contemporary science communication practices?'

To achieve the goal of connecting people with plants, botanic gardens offer diverse science communication activities aimed at engaging their audiences with plant and associated sciences. Drawing on data from 29 countries (national reports and surveys) presented in sections 4.1 and 4.2, I systematically mapped and categorised a variety of activities conducted by European botanic gardens, along with the audiences they reach. Furthermore, I explored the perception of the representatives from the national reports regarding the relevance of science communication activities in these institutions. This analysis provided valuable insights into the science communication practices employed by these institutions.

To my knowledge, this work is the most thorough overview and categorisation of science communication activities and audiences in European botanic gardens, that represent over half of all such institutions in the world. My research highlighted the prominence of *exhibitions* within the activities of European botanic gardens, including plant exhibitions and flower shows. The national reports indicated that this is closely followed by 'events' (e.g., researchers' night) and 'oral communication' (e.g., lectures). 'Guided tours', 'arts' (e.g., theatres), 'written communication' (e.g., books), and 'media' (e.g., newspapers) follow as additional, though somewhat less prominent, categories (for a detailed description of activities, see **Section 4.1**). Although certain categories, such as guided tours and media activities, are likely present across all countries, they were not consistently reported by all national reports. This discrepancy may reflect differing perceptions of what constitutes science communication within botanic gardens. It is important to note that the question posed in the national reports was: 'Special activities of botanical gardens in education and dissemination'. This phrasing may have led to varying interpretations, with some countries including for example guided tours and others omitting them, because they are routine activities and therefore not 'special'. A dedicated study investigating how European botanic gardens conceptualise science communication activities, alongside the inclusion of a direct question on this topic in future national reports, could

provide valuable insights into the practical understanding and implementation of science communication across institutions.

In addition to activities identified in previous studies of botanic gardens (Gaio-Oliveira, Delicado and Martins-Loução, 2017; Kneebone and Willison, 2007), I identified further science communication and engagement activities. Specifically: science cafés, citizen science, and co-creation activities, as well as media-oriented activities such as TV, radio, print media, and apps (e.g., smartphone app for flora identification). Many of these activities have also been found in similar nature-based institutions, such as zoos, albeit with a stronger focus on interpretation, with exhibit signage being the most prevalent medium (Roe, McConney and Mansfield, 2014). This research has also provided further insight into categories previously identified by the above authors, allowing some to be reframed. While the range of science communication activities identified by Research International (2000) (funded by the Wellcome Trust) is reflected within botanic gardens, the mere presence of diverse activities does not guarantee their frequency, reach, or impact. This highlights a need to move beyond catalogue descriptions towards an in-depth examination of how botanic gardens strategically implement and evaluate these communication practices within their unique organisational contexts. Such analysis can illuminate the ways in which institutional goals shape the effectiveness and focus of science communication efforts.

Although the categories provide a detailed overview of the range of activities offered at European botanic gardens, the national reports do not present a uniformly complete picture across individual countries. For example, 'interpretation'—a fundamental component of science communication, including basic elements such as species labels—is likely present in all botanic gardens. Yet, it was only identified in 11 out of 27 national reports and 15 out of 19 survey responses. While challenges in completing the national reports may partly explain this discrepancy, the fact that survey respondents were explicitly asked about interpretation activities suggests that such activities may be underreported because they are perceived as ubiquitous and thus not deemed noteworthy. This observation may indicate a potentially important insight: many botanic gardens may not recognise certain core activities as forms of science communication, reflecting a limited or implicit understanding of their own role in public engagement. Guided tours, which are similarly widespread, may represent another such activity that is overlooked or inconsistently reported despite their prevalence. Consequently, analysis of the national reports reveals how botanic gardens themselves classify and prioritise science communication and public engagement activities, highlighting which forms of engagement are valued and which are overlooked. This finding underscores the need to consider not only the presence of activities but also institutional perceptions of what constitutes science communication within botanic gardens. Furthermore, merchandise, when identified as a type of science communication activity (survey), was

more frequently reported in the former than in the national reports. This disparity may similarly reflect differences in how botanic gardens perceive science communication, with some activities being more readily recognised or valued depending on the mode of reporting. Based on the fact that both media and interpretation, even when explicitly identified as types of activities in the survey, are underreported, this may suggest that traditional views of botanic gardens primarily as sites for science or environmental education remain strongly rooted within these institutions. Interestingly, BGCI argues that effective interpretation actively engages visitors by helping them understand and think critically about what they see, using methods such as panels, trails, guided tours, apps, exhibitions, labels, events, and creative arts, tailored to the audience and the intended message or theme (Botanic Gardens Conservation International (no date, d).

All types of activities documented in the national reports were also reported by the survey respondents. Except for the category 'other discussion-based activities', respondents from more countries reported each activity in the survey than in the national reports. For example, while survey respondents reported that 'guided tours' were offered in all countries, this activity was not included in all the national reports. This observation further nuances the arguments presented above, suggesting that when specific types of science communication activities are explicitly prompted, botanic gardens tend to report them more frequently. This highlights potential limitations inherent in the national reporting filling, as well as revealing how these institutions practically conceptualise science communication.

In response to the question posed to EBGC country representatives in the survey about the relevance for botanic gardens of the different types of activities identified in this study, ‘guided tours’ and ‘media’ were identified as the activities more important to offer to their publics. Such activities were frequently reported in the surveys but did not feature as prominently in the national reports, possibly because they are seen as routine. As discussed above, this further underscores the discrepancy between practice and reporting.

Similar to the findings of a survey conducted by Smith and Harvey-Brown (2017) involving 200 botanic gardens across 70 countries—which revealed that public activities frequently relied on aesthetic appeal, particularly through orchid festivals, light displays, and musical events—this study also found that botanic gardens often use exhibitions and events to engage audiences with plants. However, the findings further indicate that these institutions are, to some extent, engaging in activities that extend beyond traditional one-way models of communication, possibly signalling a shift towards more contemporary, audience-centred approaches. Recent research in the field of science communication more broadly Davies *et al.* (Davies *et al.*, 2021)), found that science communicators working in

museums widely regard dialogic and participatory approaches as best practice, a shift also seen in the wider science communication literature (e.g., Bucchi and Trench, 2021: Wilkinson and Weitkamp, 2016; House of Lords (2000).

'Merchandise' emerges in this study as a communication vehicle recognised by a few botanic gardens. Certain 'merchandise' items, such as calendars featuring plant species information or seeds packets that promote awareness about the importance of native plants for conservation, effectively convey scientific knowledge and facilitate visual recognise species and have been offered by botanic gardens for many years. Previous research has also identified merchandise as a tool for education in science museums. Although merchandise has not been studied extensively as a science communication tool, as long ago as 2010, Kent argued that merchandise sold in museum shops could enhance the educational offerings of these institutions. Together with Kent (2010), my study suggests that the potential role of merchandise as a science communication tool warrants further exploration.

The social role of botanic gardens encompasses the provision of education, outreach, and recreational services, aiming to foster connections between people and the plant world (Krishnan *et al.*, 2019; Krishnan and Novy, 2017). Dodd and Jones (2010) emphasise the need for these institutions to reach and involve all sectors of the community, seeing this as essential if botanic gardens are to increase their social role. I observed that European botanic gardens are reaching diverse publics, as also identified by Kneebone and Wilson (2007). Nevertheless, a similar discrepancy between national reports and the survey was observed, with more audiences recorded in the survey than in the national reports. As above, I argue that providing predefined categories for audience types simplifies the responses process, when compared with the need to write in their own words and may facilitate a more complete picture of the audiences that botanic gardens reach.

The types of audience information included in the national reports suggests that for the compilers, the finer details of audience types are not an important consideration. For example, the broad 'general audience' category was frequently reported in both national reports and in survey responses. In addition, activities aimed at school children/education appear frequently in survey responses, but were harder to distinguish in national reports, while seniors were not easily identified in the national reports but appear frequently in the survey data. These differences suggest that botanic gardens may adopt a relatively undifferentiated view of their audiences, overlooking the nuanced needs, motivations, and backgrounds that shape public engagement. This lack of audience segmentation has been critiqued in the broader science communication literature, where it is widely recognised that a 'one size fits all' approach is insufficient for fostering meaningful and effective engagement across diverse groups (e.g. Weitkamp and Wilkinson, 2016). Furthermore, it was not possible to determine

from the national reports which activities are offered to each type of audience. This information is crucial if we are to understand how botanic gardens are meeting their goals to engage the public with plant and associated sciences.

Since it was not possible to link activities with specific audiences through the national reports, the survey asked respondents which activities they believe engage each target audience most effectively. In this regard, activities such as arts-based initiatives, guided tours, events, training sessions, oral communication, exhibitions, and interpretative displays were most frequently reported by country representatives as effective means of engaging audiences. This suggests a prevailing tendency towards science communication approaches that are more closely aligned with one-way models of engagement. A study conducted by Afonso *et al.* (2022) on a mobile science museum reported similar findings, the predominance of one-way approaches of science communication.

Although the analysis of national reports (**Section 4.1**) allowed for the outline of a broad panorama of activities and audiences in European botanic gardens, it also presented challenges and limitations of interpretation, mostly arising from missing or unclear information and inconsistent reporting across countries. It is also possible that some countries may not have considered all types of activities worth reporting when preparing their national reports, adding only the exceptional activities. Although more evidence is needed, underreporting of common or ubiquitous activities seems to happen in similar institutions. For example, a similar situation has been observed in zoos (Roe *et al.*, 2014). In this study of communication activities in 176 zoos worldwide, zoos were likely to miss communication activities when surveyed, as the authors, in a subsequent fieldwork period at nine of the zoos, observed a much more diverse array of activities taking place.

In summary, **Section 6.1** addresses key aspects of RQ1 by examining the science communication activities and audiences of European botanic gardens. The data reveal a wide array of initiatives—from traditional exhibitions and guided tours to emerging forms such as citizen science and co-creation. However, inconsistent reporting practices and the perceived ubiquity of certain activities suggest a lack of shared conceptual clarity across the sector, potentially leading to under recognition of their communicative value. Although botanic gardens aim to reach broad publics, the frequent use of generic audience categories indicates limited evidence of audience segmentation. To some extent, this suggests that science communication practices are not systematically tailored to the specific needs, interests, or motivations of diverse audience groups. These findings highlight an opportunity for botanic gardens to adopt more targeted and reflexive engagement strategies that align with the pluralistic goals of contemporary science communication.

6.2 Connecting people with plants: practices in British and Portuguese botanic gardens

In this section, I aim to address aspects of RQ2, through a detailed analysis of two case study countries, the UK and Portugal:

'How are these practices reflected in different national and cultural contexts?'

To deepen understanding of science communication practices conducted by botanic gardens, the United Kingdom and Portugal were selected as model countries for this study. Drawing on data from interviews with 28 participants, 17 from the UK and 11 from Portugal, I have mapped and categorised a variety of activities conducted by botanic gardens from these two countries, along with the audiences they reach, to provide insights into the scope and nature of engagement. Furthermore, I compared how science communication practices are reflected in both countries (**Section 4.3**). The UK and Portugal were selected as case study countries, as they are representative of the institutional and cultural diversity of European botanic gardens. Additionally, these are the two languages in which I am fluent for conducting interviews.

Activities

The science communication activities reported in the interviews prompted a reorganisation of the categories previously identified in national reports, enabling a more detailed and empirically grounded framework. The identified 14 categories (see **Section 4.3.1** for more detailed information) offer a more nuanced and comprehensive classification of science communication practices in botanic gardens. Notably, the absence of 'written communication'—a category present in earlier reports and surveys—highlights how science communication is perceived by practitioners of these institutions.

Drawing from the dissemination and participation models of science communication (Bucchi and Trench, 2021), and two-asymmetrical model of public relations (Grunig and Hunt, 1984), most categories of activities seem to fall into one-way communication approaches. This observation also corresponds with the categories identified in prior studies by Gaio-Oliveira, Delicado and Martins-Loução (2017) and Kneebone and Willison (2007).

Regarding the similarities between UK and Portugal, the activities identified under 'tours' were mentioned by all participants in both countries and appear to play a pivotal role in the activities offered by botanic gardens to their visitors. Kneebone and Willison (2007) also identified 'guided tours' as the most frequently mentioned activity in their study.

Pertaining to distinct cultural contexts, participants from the UK have reported a greater diversity of activities than those from Portugal, and further inside each category the examples of activities were different. For instance, 'merchandise' was identified only in the UK, and regarding 'oral communication', only online talks were reported by British participants. Interestingly, although quite common in the UK botanic gardens, only one participant of the study addressed it as a science communication practice. The 'training' category was also only reported by UK participants, though anecdotally I know it exists in Portugal. This suggests that science communication practices may vary between countries. In a study conducted by Davies *et al.* (2021) across seven European countries, differences in science communication practices were identified in various national contexts. For example, science communication on social media is conducted differently in the UK compared to Italy.

One interesting difference was in the category 'digital communication'. Here, Portuguese participants mentioned social media and newsletters, while British did not, even though both activities occur in the UK, possibly because these were not seen as prominent activities associated with the roles adopted by participants in Britain. This may relate to the roles adopted by the study participants, since these activities may be more often associated with the translator role which was more prominent in Portugal than the UK (see **Section 6.3**). Furthermore, for the category 'media' only Portuguese interviewees reported producing press releases, also possibly linked to their adoption of a translator role.

Public consultation was only mentioned by UK participants. I did not find any information about this practice in Portugal in the grey literature, nor do I have anecdotal knowledge of it. In this case, the societal drive to embed participatory activities within science communication may play a role in shaping the practices of participants. With a long history, science communication in the UK is driven by a dynamic mix of government policies demanding measurable impact, institutional funding incentives, and the development of researcher training programs. This evolving landscape reflects a diverse ecosystem where multiple approaches coexist and adapt to changing societal and institutional priorities (Broks *et al.*, 2020). In contrast, in Portugal, national science communication policies promote a culture focused on increasing scientific literacy, often highlighting unidirectional 'deficit' models of communication, which also suffer from lacking resources and professionalisation (Broks *et al.*, 2020)

In this thesis, a spectrum of levels of visitor involvement was described by the interviewees who conducted guided tours. While all of them welcome visitors' questions, some exhibit greater flexibility in tailoring the tour content to meet audience expectations. For instance, during school visits or themed visits, study participants tend to adhere more strictly to the predetermined tour content, likely due to the need to meet specific educational objectives or curriculum requirements. Such visits often have clearly defined learning outcomes that require communicators to maintain a structured approach

to ensure these goals are effectively addressed. An observational study conducted by Zhai and Dillon (2014) analysing professional botanic garden educators' talk during guided school visits found that although there were occasionally dialogic interactions, a non-interactive/authoritative communication approach was the most common practice. Additionally, the authors identified that both storytelling and analogies were frequently used by the guides (Zhai and Dillon, 2014). This aligns with my findings that during school visits, communicators tend to adhere closely to predetermined content, likely reflecting the need to meet specific curricular goals. In contrast, for other visitor groups, interviewees from this study reported a greater willingness to inquire about audience interests and adapt tours accordingly, demonstrating more audience-centred and flexible communication approaches. This contrast highlights how the context and audience type significantly influence the extent to which communicators engage in dialogic versus didactic practices in botanic gardens. My research sheds light on the different ways that tours might align with science communication theory and practice. Recent years have seen a strong push for more dialogic approaches to science communication (Weitkamp and Almeida, 2022; Bucchi and Trench, 2021; Davies *et al.*, 2021; Rock, McGuire and Rogers, 2018) and while tours may not enable participants to contribute to science, they do enable more two-asymmetrical way of communication (Grunig and Hunt, 1984).

Participatory approaches in botanic gardens

High visitor numbers, connections with local communities, and access to plant and associated sciences experts mean botanic gardens are valuable places for hosting citizen science projects (Primack *et al*., 2021). One of the definitions for citizen science is 'projects actively involve citizens in scientific endeavour that generates new knowledge or understanding' (European Citizen Science Association, no date). However, this definition encompasses a wide range of involvement levels, from so-called citizens as sensors projects to those that are shaped by citizens to meet citizen objectives (Metcalfe *et al.*, 2022). The citizen science projects described by participants from both countries in this study portray botanic gardens as places where citizens can actively participate in knowledge generation but not shape it, where UK demonstrated a greater diversity and consistency of such initiatives.

Since these institutions work closely with local communities, hold a societal role, and have a mission to address biodiversity loss, climate change, and other environmental issues, I argue they have the skills to collaborate with citizens thought a grassroots approach to create a green community hub to empower the local citizens, a challenge they have yet to rise to. This untapped potential presents an important opportunity for botanic gardens to deepen community engagement by fostering more

collaborative, citizen-driven science initiatives that empower local communities and strengthen their societal role.

According to Rock *et al*. (2018), in the science communication field, the concept of co-creation needs careful definition. For this study, co-creation is conceptualised as a participatory methodology that requires the target audience to actively participate in the development of the intended product, where mutual feedback and knowledge are equally valued and integrated among all involved parties. Looking through the lens of botanic gardens, co-creation takes different forms. In Portugal, it is used to target audiences who do not typically visit the garden, through co-creation approaches with representatives of specific target audiences, with a view to encouraging these communities to visit. A broader range of goals were identified for co-creation activities in the UK, where it is employed to develop activities, materials for activities, and as a strategy to engage with ethnic minorities.

The literature reveals a co-creation project with more complexity and public involvement than those mentioned by the participants: The 'Big Picnic: Big Questions – engaging the public with Responsible Research and Innovation on food security'. This project involved 15 European botanic gardens (including one botanic garden from the UK and one botanic garden from Portugal) and other partners, including BGCI, where experts and local communities collaborated to co-created exhibitions, sciences cafés, and other activities aimed at addressing food security issues (Alexopoulos and Moussouri, 2021). This evidence suggests that while botanic gardens have the potential to engage in meaningful co-creation with their audiences, as exemplified by large-scale projects like 'The Big Picnic, the examples from the UK and Portugal in this study indicate that such deep participatory practices are not yet widespread or consistent, although resources and toolkits developed through this project are available for these institutions to use. Understanding these gaps highlights opportunities for botanic gardens to expand their role in science communication by fostering more collaborative and community-driven initiatives, which aligns with the broader aims of this research to explore how botanic gardens reflect and embody contemporary science communication practices. In addition to the Big Picnic project, the project 'Community in Nature' led by BGCI (Vergou and Willison, 2016), sought participation during their implementation. This project aimed to enhance the social role of botanic gardens through a two-way engagement with local communities. However, as above, these types of projects are temporary, suggesting that many botanic gardens may require external funding or expertise to implement these types of initiatives.

Public consultation activities involve gathering information from the public and subsequently integrating it into the intended product. However, it differs from co-creation because public participation in public consultation tends to be provision of information rather than active

collaboration in the creation process (Curry *et al.*, 2024). This approach was exclusively mentioned in the UK context, where botanic garden staff seek input or feedback from the public on diverse matters, including the types of activities to offer to the visitors, horticultural knowledge, and creating engaging information for interpretation panels. There are also examples in the literature of public consultation initiatives led by botanic gardens. For instance, the Botanic Garden Conservation International (BGCI) held a public consultation call to gather input from users and potential users of the Global Biodiversity Standard (BGCI, no date, e). Another example is a collaborative effort involving Sefton Council, the Botanic Gardens Community Association, and other organisations, which conducted a public consultation to solicit feedback aimed at enhancing the garden and other green spaces within the borough (Growth Platform, 2022). These projects suggest that in the UK the botanic gardens may see benefits from public consultation; they provide a way to engage the local community, to obtain feedback to improve their service to the visitors, and perhaps a way to get sponsors and funding though collaborative projects. These and other drivers may be absent in Portugal, accounting for the lack of such projects being mentioned by interviewees.

Audiences

Similar to the activities, the interviews enabled me to refine and elaborate the audience in 17 categories that better reflect the realities of botanic gardens (see **Section 4.3.2** for more detailed information). As with the types of science communication activities, I observed differences and similarities between the UK and Portugal in terms of the audiences that botanic gardens try to reach. On the one hand, the UK showcased a more diverse range of target audiences compared to Portugal. On the other hand, I identified parallels in the main audiences of both countries, namely schools, families, and the general population. Dood and Jones (2010) provided a self-completion questionnaire to some UK botanic gardens (plus one Australian and one American) about the audiences for whom they provide activities. As in my study, schools and general public were the audiences most frequently mentioned by those respondents. Moreover, Kneebone and Willison (2007) identified school children as the main target audience, as the category 'general public' was not included in their predefined groups. In contrast, Gaio-Oliveira, Delicado, and Martins-Loução (2017) found that the general public was the primary target audience for some activities, while children were the main audience for others. The prevalence of the general public as a target audience aligns with observations from the national reports, highlighting the need for botanic gardens to adopt more detailed audience segmentation to implement more effective science communication practices.

Institutional strategy may be an important factor that encourages staff to engage with wider groups, such as vulnerable people or people with additional needs, as UK participants who mentioned activities designed to engage with those audiences usually have an institutional strategy identifying these groups as priorities.

In summary, **Section 6.2** addresses key aspects of RQ1 by providing a deep dive comparison between the UK and Portugal. The observations suggested that national context affect the science communication practices in botanic gardens. The UK reported a greater diversity of science communication activities, including unique categories such as merchandise, as well for target audiences. However, the main audiences were similar between countries. Regarding communication styles, one-way communication approaches appeared to be more prominent in Portugal, potentially reflecting broader structural and institutional influences on science communication practices.

The following reflection offers an interpretative insight informed by the knowledge acquired throughout the course of this thesis, by grey literature, and by my prior knowledge. While some of the observations made are not grounded in a systematic analysis, they serve to contribute to a broader understanding of practices of science communication within botanic gardens. Importantly, the intention here is not to speculate but rather to reflect critically. The field of science communication in botanic gardens is largely unexplored, with few studies that address science communication activities and audiences in these settings. The existing literature tends to consist of isolated case studies, offering limited insights into broader trends. In contrast, science museums and centres benefit from a more established body of research. For instance, the well-known books for the science communication scholarship 'Handbook of Public Communication of Science and Technology (e.g., (Bucchi and Trench, 2021b) have a chapter dedicated to science museums and centres. It is this contrast that highlights a key issue: the prioritisation – or lack thereof- of both, botanic gardens in science communication and science communication in botanic gardens.

From my research and personal experience, botanic gardens seem to offer few interactive and immersive experiences, something that has become more common in science museums and centres (Bell, 2008). It may be that these institutions are more visitor-orientated than botanic gardens, creating a driver for their public engagement. Furthermore, botanic gardens face competing institutional priorities that are not shared with science museums and centres, such as plant conservation and hosting living collections which require significant resources. These are foundational goals that directly

align with the core mission of botanic garden but often take precedence over science communication. As result, while science communication is recognised as important, my research suggests that it does not occupy the same central role in botanic gardens as it does in science museums or centres.

This does not imply that botanic gardens engage in less science communication per se. Rather, it suggests that science communication, while valued (for example, Botanic Gardens Conservation International offers numerous resources for it), is often subordinate to other institutional objectives. As my research shows, in many cases, the activities are primarily focused on school groups and curricula, with fewer public-facing activities designed to engage broader audiences. The limited scope of fixed-term activities in botanic gardens, compared to the more diverse programming in science museums or centres, reflects this prioritisation. While notable exceptions exist, such as the Royal Botanic Gardens, Kew, exist. Nevertheless, all interviewees in this study emphasised the importance of science communication in botanic gardens, expressing strong desire to improve and expand their efforts within their institutions.

6.3 Science communicators within the context of botanic gardens: perspectives from the United Kingdom and Portugal

In this section, I aim to address the RQ2:

> '*How do communicators working in botanic gardens embody science communication within distinct cultures?*'

To understand how science communication is integrated by the staff of botanic gardens involved in communication, the research explored their perspectives on the field (**Section 5.1**), their aims when communicating with their audiences (**Section 5.2**), the roles they adopt towards their audiences (**Section 5.3**), and their conceptualisation of the botanic gardens – society interaction (**Section 5.4**). This discussion is drawn from the thematic analysis done with the interviews of 28 participants, namely 17 from the UK and 11 from Portugal.

Science communication and science education

Given that botanic gardens frequently have an explicit educational mission (Krishnan, S. and Novy, A., 2017), I sought to understand how interviewees positioned themselves in relation to both science communication (see **Section 2.1** for definition) and science education (see **Section 2.2.2** for definition)

(**Section 5.1**). Some of study participants see themselves as science communicators, while others as science educators. Interestingly, some participants clearly identify as science communicators and science educators, the overlap in self-identification highlighted the fluid and sometimes ambiguous boundaries between science communication and science education.

Participants who identified as science communicators conceptualised science communication as a dynamic process aimed at engaging audiences, facilitating dialogue, and enhancing public understanding of science, in this case plant and associated sciences. They emphasised creating a two-way interaction that fosters mutual understanding and engagement between botanic gardens and the public. Their concepts often aligned with the AEIOU vowel framework (Burns, O'Connor and Stocklmayer, 2003) —awareness, enjoyment, interest, opinion-forming, and understanding. However, their conceptualisations may also reflect an idealised or normative understanding of science communication, which does not necessarily imply that all their activities are developed and delivered according to these assumptions. As such, while participants describe their work in terms aligned with the AEIOU vowel framework (Burns, O'Connor and Stocklmayer, 2003), the extent to which this is consistently realised in practice remains open to further investigation.

Indeed, the act of translating scientific information for public audiences is a recognised form of science communication (Bucchi and Trench, 2021). Rather, the point is that, although participants self-identify as science communicators, this does not necessarily mean that all conceptual dimensions of science communication are fully embedded in their practice.

In contrast, participants who identified as science educators often hold a narrower view of science communication. They perceive it primarily as an instrument for science education, focusing on the dissemination of scientific knowledge or as a means of translating complex information for public consumption. Some participants view science communication as comprising only one-way approaches, where information is transmitted without necessarily promoting deeper understanding, critical thinking, or active learning among audiences. Similar findings were found by Nerghes, Mulder, and Lee (2022), who explored the conceptualisation of science communication with a group of scientists. They found that for most study participants science communication means:

> *'A one-way process of transmission and translation of scientific results and their impacts towards a lay audience, via mostly traditional media channels, with the goals of making science more accessible, of educating audiences, and of raising awareness about science'*.

As highlighted in the study above, science communicators may hold narrow and dated views of science communication, despite the scholarship of science communication addressing the problems of the deficit model for at least for 25 years (Suldovsky, 2016).

A study conducted by Barbolini (2022), exploring university-level pedagogy and public science communication, points to an overlapping goal, namely dissemination of knowledge from the expert to non-experts. The author observed that education and public engagement are also often perceived as distinct fields with little to learn from each other. However, both within university pedagogy and wider science education, there are moves to conceptualising education as a more dynamic and two-way process (Lubicz-Nawrocka, 2023), which align with shifts in science communication away from the deficit model of this study. Some of the participants of this study who identified as science educators, see science education as a two-way approach. Based on these observations, it seems plausible to argue that those who identify as science educators may be drawing narrow definitions of the field of science communication, as has been noted by several scholars, e.g., Barbolini (2022). The decision to identify oneself primarily within a science communication or science education framework may also be influenced by educational background and training -or lack of- in science communication. For example, several participants in the UK who identified as science educators had come from educational backgrounds and in Portugal all participants had backgrounds in the natural sciences. The degree to which they have engaged with contemporary science communication theories and practices could be explored further to shed light on this issue.

Some of the participants who identified as both science communicators and science educators held perspectives that reveal a nuanced understanding of the fields. This allows them to integrate elements from both domains, e.g., education and translation. These participants often perceive science communication as a versatile tool that serves multiple purposes within botanic gardens and similar settings. They acknowledge its role in disseminating scientific knowledge to diverse audiences while also emphasising its potential to foster deeper understanding, critical thinking, and active learning among visitors. These observations about the relationship between science communication and science education in botanic gardens suggests a need for more integrated professional development opportunities that bridge these conceptual frameworks, enabling practitioners to adopt a more holistic approach to their roles. Future research might also explore how these identities influence the design and delivery of activities within botanic gardens and similar institutions.

Regardless of the point of view of participants, if we have a look at institutional terminology, science education or environmental education are the terms more often employed. For example, BGCI identifies science communication as one of the four components for the best practices for botanic

garden education (no date, c); the Big Picnic project outputs for botanic gardens were named 'educational toolkit' (Botanic Garden Conservation Internation, no date, f). Research also addresses the activities of botanic gardens as environmental education (Sanders, Ryken and Stewart, 2018) or education (e.g., Jones and Dones, 2010). On the Royal Botanic Gardens, Kew website the term used is learning, which could imply education but is also used in the science communication field. This wider institutional framing of their activities as educational may also be one reason some staff view themselves as science educators.

From an educational perspective, a study by Tran (2008) similarly revealed a divergence in how museum staff involved in education perceive their roles. Some staff members characterised their work as 'teaching,' while others identified it as 'delivering,' 'facilitating,' or 'presenting.' This variation in terminology highlights the complexity and lack of consensus surrounding the role of educators within such institutions, raising important questions about the underlying assumptions and expectations associated with each term.

I believe this is one of the first studies to explore the perspectives about science communication and education with non-scientists (in this case botanic gardens staff) and to find different self-identifications, from the dynamics of science communicator and science educator to two participants who did not identify as either. In Portugal, one participant identified as a discussant, believing everyone has the capacity to engage in discussions, which is also his purpose, to facilitate debates about plants and associated sciences. In the UK, another participant identified as a facilitator, probably because they view their role as organising and providing the necessary arrangements for audience experiences. Interestingly, neither of these participants see themselves secondarily as science communicators or science educators. This suggest that the professional identities within the field of science communication can be more varied and complex than traditional labels might imply. On a larger scale, Roche *et al*. (2023) illustrated this complexity in a global study of science communicators. This study asked participants to identify with a set of labels for their role as science communicators; the most common role reported was of scientist or researcher, followed by science writer or journalist, science teacher or educator, and science communication researcher.

According to Cambridge dictionary, communicate means *'to share information with others by speaking, writing, moving your body, or using other signals'*, while education is defined as *'the process of teaching or learning, especially in a school or college, or the knowledge that you get from this'*. Within education, teach means *'to give someone knowledge or to train someone; to instruct'* and learning refers to *'the activity of obtaining knowledge'*. Therefore, aside from the academic component of both science communication and science education, and considering the practical aspect of it,

education means to give, and communication means to share. Moreover, teaching implies giving, resembling the deficit model, and, in my opinion, the word educate does as well. Although learning means obtaining knowledge, it is somewhat reductive because it implies that the public are merely receivers, which, unfortunately, is often the reality of botanic gardens. On the other hand, share means *'to have or use something at the same time as someone else'*.

Therefore, I believe the term science communication better fits the purpose of botanic gardens because they aim to do more than just educate people. Furthermore, science education could suggest to the public that they lack knowledge, are mere vessels for information, and that botanic gardens are not a space for knowledge exchange and mutual understanding, or a space where they do not have a voice. Furthermore, I propose that the term environmental communicator should be used to describe this profession. I believe environmental is more accurate than science for botanic gardens, a vision shared by some participants of this study. Additionally, the public might feel science is not for them, creating a barrier to engagement. In conclusion, this profession should be called environmental communicator, drawing on theorical frameworks from science communication, science education, public relations, and perhaps even marketing (for example, conservation sciences have recently started to incorporate marketing theory - e.g., Salazar, Mills and Veríssimo (2019)). This approach acknowledges the broad and inclusive nature of the work being done in botanic gardens, promoting a more dynamic and reciprocal relationship between the public and the environment.

Aims

Regarding the aims of participants during their communication activities (**Section 5.2.**), participants from both countries shared similar thoughts, except for promoting botanic gardens, which was only identified in the UK. This difference may be due to institutional strategies and visions. Creating an engagement environment and facilitating learning for their audiences are the most common goals across participants from both countries, suggesting the overall aims are not shaped by national context, with the possible exception above.

Wilkinson *et al.* (2022) investigated the aims of European science communicators, finding that information and education were the most prevalent goals, which mirrors the findings of this study to some extent, since facilitating learning was one of the two predominant aims offered by the interviewees. The other aims found in this study also are present in Wilkinson *et al.* (2022), however adapted to each study's reality. Nevertheless, the authors identified aims that I have not identified during the interviews, such as to reach underserved audiences, though to an extent this was implied

by the range of audiences identified by interviewees. Besley *et al.* (2016) conducted interviews with science communication trainers to explore their perspectives on goals and objectives in science communication, categorising the data into communication goals, communication objectives, and communication skills. Communication objectives included goals such as to increase knowledge and fostering excitement, which I also identified. Communication skills such as being brief and clear, and knowing your audience, were also recognised by the staff of botanic gardens. Thus, in an overall analysis, the interviewees in this study share similar aims with other science communicators from different contexts.

Roles

For the purposes of this study and drawing on the literature review (see **Section 2.3.2**), a role is defined as the actions or behaviours undertaken by science communicators to engage with their audiences. Identifying and examining these roles offers a valuable lens through which to understand how communicators operate in different institutional and national contexts, and how science communicators tailor their strategies to suit diverse audience needs, potentially enhancing the effectiveness and inclusivity of their outreach. Although not yet empirically verified, it is plausible to argue that different audience groups may benefit from communicators adopting different roles. For example, audiences with low initial interest or engagement in botany and related sciences may respond more positively to science communicators who primarily adopt an entertainer role. Moreover, a clearer understanding of roles can inform targeted professional development, as it highlights the skills and competencies associated with various aspects of science communication within a specific context, in this case botanic gardens. From an evaluative perspective, this framework may also facilitate more robust assessments of communication practices.

Regarding the roles that participants could adopt with respect to their audiences, I have identified seven roles enacted by science communicators in botanic gardens: broker, educator, engager, entertainer, includer, listener, and translator (**Section 5.3**). Two of these—engager and translator—emerged as new contributions to the literature. The framework was informed by Milani et al. (2021), who explored science communicator roles across a range of European institutions, excluding botanic gardens. In contrast to their findings, this study did not identify the enabler role and instead contributed two novel categories. As visualised in the literature review (**Table 1**), the engager role falls within the engagement dimension, while the translator aligns with the informative dimension. This suggests that communicators in botanic gardens occupy roles spanning all dimensions of science communication (informative, educative, engagement, advocacy, and empowerment). Interestingly,

Milani *et al.* (2021) did not identify the informative dimension, thus my study adds a new dimension to the literature on science communication roles.

The translator role was adopted by all Portuguese participants and was the only role consistently present across that national sample. In contrast, British participants adopted a more diverse range of roles, with no single role consistently observed. This suggests that Portuguese communicators may be more inclined towards a one-way, transmission-oriented model of science communication. Further research is needed to explore whether this pattern reflects a deeper institutional or cultural orientation towards a traditional model of science communication in Portugal. A view supported by Broks *et al.* (2020) who argue that Portuguese science communication is more oriented towards the deficit model.

One of the factors that could explain the divergence in the roles adopted by interviewees is their educational background. For example, arts and humanities backgrounds are exclusively present amongst British participants, additionally, an academic background in education is more prominent in the UK than in Portugal, where all participants have backgrounds in the natural sciences. Although no clear pattern emerged when comparing educational background with the roles adopted, study participants with a background in arts and humanities appeared more likely to assume entertainer and engager roles. Another significant factor could be the UK's strong tradition in public engagement (Broks *et al.*, 2020), where science communicators are less likely to approach their jobs from a purely translational perspective. For instance, as noted in the literature review (**Section 2.1**), the challenges and debates surrounding different paradigms of science communication have been extensively addressed in the UK, notably through influential documents such as the Bodmer Report (1985) and the House of Lords Report (2000). These discussions have significantly shaped the development and evolution of science communication practices within the UK, and the scholarship. By contrast, Portugal has largely followed these developments rather than initiating similar critical debates independently, which may partly explain differences in science communication between the two contexts. Furthermore, in the UK, some botanic gardens have larger teams dedicated to education and communication, which may contribute to greater diversity in the roles assumed by science communicators, enabling greater specialisation, for example. Consequently, research examining the relationship between job positions and the roles adopted may help to explain the observed diversity of roles within UK botanic gardens.

Visitors' expectations and participation may further contribute to this divergence. Through the interviews, I identified that the UK seems to have more varied and numerous volunteering programmes and actions in botanic gardens than Portugal. Additionally, the ethnic diversity of local

communities may influence the roles adopted by science communicators (Dawson, 2014). Overall, the combination of educational background, institutional support, public engagement traditions, visitor expectations, and community diversity may contribute to the distinct roles profile observed between the UK and Portuguese participants.

Botanic garden communicators' conceptualisation of botanic-gardens society interaction

Another aspect of RQ2 was to assess whether there are differences between countries in the ways that botanic gardens staff conceptualise the interaction between botanic gardens and society. A conceptualisation is the interplay between knowledge production (science) and knowledge use (society), and the types of communication activities that contribute to varying levels of this interplay (**Section 5.4**). A conceptualisation is necessarily mediated by communicators and reflects their practices and understandings. The work of Milani *et al.* (2021) served as the framework for this section; the authors identified supplying, bridging and facilitating as conceptualisations. I reframed the latter two as collaborative and participatory conceptualisations (see **Section 5.4** for more detailed information) to reflect the reality of botanic gardens more accurately.

The three distinct approaches I identified, namely supplying, collaborative, and participatory, illustrate a spectrum from knowledge delivery to active audience participation. However, the supplying approach was the predominant conceptualisation observed; it is characterised by a one-way dissemination model of science communication (Bucchi and Trench, 2021) or a two-asymmetrical communication model from public relations (Grunig and Hunt, 1984), similar to the findings of Milani *et al.* (2021) All study participants referred to this conceptualisation, with no evidence of differences between countries. However, since the translator role (which could be directly connected with the supplying conceptualisation) is more predominant in Portugal than in the UK, different nuances could exist in the approach taken within the supplying conceptualisation between both countries. Further work is needed to uncover these nuances, possibly in the form of observational studies on how science communicators from both countries engage with their audiences.

The collaborative conceptualisation involves a two-way exchange of knowledge, but where the authority of experts was maintained. It aligns with the two-asymmetrical communication from public relations (Grunig and Hunt, 1984). While present in both countries, this approach is more prevalent in the UK than in Portugal. Similarly, the participatory conceptualisation was identified in both countries, but with greater prevalence in the UK. It advocates for the integration of user knowledge through two-way communication, valuing both sides of knowledge equally. However, when study participants

adopted a participatory conceptualisation of science communication, audience involvement was consistently embedded within the activity design (e.g., co-creation) or data collection (e.g., citizen science). As such, these practices align more closely with the participatory model of science communication, rather than the dialogue model (Bucchi and Trench, 2021).

The dialogue model (Bucchi and Trench, 2021), as viewed through the lens of science communication scholarship, was not observed in the botanic gardens of the UK and Portugal. The dialogue model promotes mutual learning between scientists and non-experts, emphasising the equal value of scientific, cultural, and experiential knowledge, and encouraging dialogue on the practical implications of science (**Section 2.1**). From my observations, it appeared that mutual learning between botanic garden staff and the public often tends to be instrumental—primarily aimed at gathering knowledge, or input from audiences, as seen in practices such as public consultations, citizen science, or co-creation initiatives. This suggests that engagement is frequently framed around the utility of public contributions, rather than to shape science. Furthermore, when botanic gardens do conduct research, it is typically grounded in botany—an area that may not readily lend itself to meaningful public input, thus presenting additional challenges for a genuine dialogue model. Although situated in a different context, Rao (2023) argues that the applicability of various paradigms of public engagement varies across scientific fields. This is due to the different impacts of applied and fundamental sciences, as well as the extent to which lay audiences can relate to or identify practical relevance in certain scientific topics. Furthermore, Rao found that particle physicists tend to be more aligned with the deficit model, because the research context does not lend itself to meaningful lay participation. My research suggests a need to adapt the models of science communications to accommodate the realities of institutions like botanic gardens, which are scientific but typically not research centres. I argue for the development of a framework which incorporates models from science communication (**Table 10**), namely dissemination and participation, with models from public relations, namely two-asymmetrical communication model. Such a framework (**Table 10**) may better explain the reality of botanic gardens and may also be a suitable model to reflect the realities of other scientific institutions that are not typically research centres, such as science museums or zoological gardens.

Table 10. Proposed framework for models of communication in botanic gardens. This framework draws on the model proposed by Bucchi and Trench for science communication (Bucchi and Trench, 2021) and the communication models developed by Grunig and Hunt (1984) in the field of public relations.

Models	**Dissemination**	**Involvement**	**Participation**
Direction of communication	One-way	Two-away asymmetrical	Three-way
Purpose	Informing; knowledge transfer	Interaction; influence; gather feedback	Mutual understanding; co-creation
Public role	Passive receiver	Active receiver or supplier	Active contributor
Value of public input	Low to none	Instrumental or selective	Central and valued equally
Outcomes	Information, awareness, learning	Persuasion; insights for practice	Sharing ownership, empowerment, creating

The dissemination and participation models in the proposed framework reflect the same assumptions as those outlined by Bucchi and Trench (2021). However, the dialogue model of communication in the framework of these authors presume that audiences can shape science, a reality that I have not found at botanic gardens. However, while their dialogue model presumes that audiences can actively shape scientific processes, this level of engagement was not observed in the botanic gardens examined in this study. Instead, the practices I encountered more closely align Grunig and Hunt (1984) two-asymmetrical model of communication. However, as the latter was originally formulated within a corporate and profit-driven context, I have opted to reframe it as involvement to use terminology more suitable to the nature of botanic gardens: connecting people with plants. This adjustment helps to ensure that the framework is better aligned with the intention of science communicators within botanic gardens.

The dissemination and participation models represent the two ends of the spectrum of science communication practices observed in botanic gardens. The involvement model, as proposed in this framework, encompasses a spectrum of practices that vary in the extent of audience engagement. At one end, it may resemble the dissemination model, but here the communicators aim to stimulate audience attention and interaction (e.g., through rhetorical or interactive tools). At higher levels of involvement, audiences are encouraged to provide input, share experiences, or contribute knowledge that may inform the work of science communicators. However, unlike the participatory model, which is grounded in mutual learning and shared authority, the involvement model retains a hierarchical structure. Here, communicators typically maintain control over how audience input is interpreted and used, preserving their authority over final outcomes. Thus, while the involvement model promotes a degree of responsiveness and conversation, it does not fully decentralise expertise or decision-making.

In sum, I argue that staff within botanic gardens embody the full spectrum of science communication practice typically seen in non-research institutions. Their roles range from delivering information in a one-way format to facilitating more participatory and engaging approaches; from acting as translators to adopting inclusive practices; from designing curriculum-based educational activities to offering non-formal learning experiences; and from leading guided tours to engaging in co-creation. They interact with both traditional audiences (e.g., school groups) and more marginalised communities (e.g., socially excluded individuals). However, in general, the day-to-day reality of their work appears to be aligned with more traditional practices of science communication. This is evident in the prevalence of guided tours and school-focused activities, which reflect a supply-led conceptualisation of their relationship with society. I would suggest that this is less a matter of personal inclination and more a consequence of institutional missions, available resources, staff training, and time constraints.

Crucially, regardless of country, role, or whether participants identified as educators or communicators, etc., all expressed a deep commitment to their work and a shared enthusiasm for connecting people with plants. This passion serves as a foundation upon which more innovative and inclusive practices could potentially be developed, given the right resources.

Chapter 7

CONCLUSIONS

Science communication is typically understood as the exchange of knowledge between scientists and the public (Research International, 2000). Botanic gardens and other science-based settings are active players in this field, encompassing a diversity of activities and engaging diverse audiences as part of their daily operations. Thus, these organisations also contribute to public understanding and engagement with science and strengthen the relationship between science and society.

In this thesis, I have explored the role of science communication within botanic gardens, through answering the following research questions:

RQ1: *'How do botanic gardens reflect contemporary science communication practices?'*

RQ2: *'How do communicators working in botanic gardens embody science communication within distinct cultures?'*

To achieve RQ1, I examined science communication activities through an institutional lens, by mapping the science communication activities offered by botanic gardens and their target audiences. Secondly, I analysed the perspectives of science communication practitioners to deepen my understanding of the roles of these organisations. Thirdly, I examined the UK and Portugal to deepen the understanding of science communication activities and audiences, and I explored how national contexts may influence science communication practices in both countries. To accomplish RQ2, I assessed practitioners' views of the field, the aims of their communication, the roles they adopt towards their audiences, and their conceptualisations of the interaction between botanic gardens and society. These two dimensions are now considered and used to draw out recommendations.

7.1 RQ1: 'How do botanic gardens reflect contemporary science communication practices?'

To answer RQ1, firstly I started by catalogue the types of science communication activities and audiences presented in the national reports of European botanic gardens. The analysis of the national

reports and surveys provided the largest overview to date of the science communication activities conducted by European botanic gardens, which have been organised into categories aligned with differing models of science communication (Bucchi and Trench, 2021) and public relations (Grunig and Hunt, 1984). I found that these institutions offer a wide range of activities to the public, from passive forms such as talks, to highly active forms like citizen science, and passing through forms with some level of interactivity such as hands-on activities. There is a preponderance of activities with a passive nature with few opportunities for truly mutual learning, which may relate to botanic gardens being both visitor attractions and research organisations. Nevertheless, these institutions do not have strong research traditions such as universities, and therefore opportunities for two-symmetrical communication are more limited.

Alongside this initial characterisation of the activities of botanic gardens, I examined the audiences that European botanic gardens try to reach. The institutions aim to engage a wide spectrum of audiences through activities designed for broad groups such as the general public, adults, and families, to more specific groups like stakeholders and audiences with special needs. Additionally, they offer tailored activities across all schools' levels, including educators. It was apparent from the analysis of national reports that while a wide array of audiences might be reached, these may not be clearly differentiated. Further analysis of data from surveys found that general audience is present in all countries, reinforcing this idea. Additionally, the survey permitted more detailed insights into the perspectives of botanic garden country representatives regarding science communication activities and their intended audiences. The activities identified are often based in one-way approach.

Secondly, I explored the perceptions of the representatives responsible for the national reports about the relevance of science communication activities in botanic gardens. Here, I observed a preference for one-way communication approaches, such as guided tours over more dialogic approaches, such as consultation those these were mentioned.

Thirdly, I investigated science communication activities and audiences at UK and Portuguese botanic gardens, and how their practices were reflected between both countries. I observed a notable difference between the two countries. The UK reported a greater diversity of activities within categories, such as public consultation, and across the number of categories of activities present, for instance merchandise, a new vehicle for science communication than has not been considered before in the context of botanic gardens. Similar findings were observed in relation to the audiences they try to reach, though the participants from UK mentioned a great diversity of audiences such as vulnerable people and ethnic minorities. Furthermore, one-way approaches seemed to be more widespread in

Portuguese practices, a fact that could be explained by the UK's longer tradition of science communication compared to Portugal.

By integrating findings from national reports and interviews, an extensive framework was developed to depict the landscape of science communication activities and audiences within European botanic gardens. This framework offers a guideline for botanic gardens to characterise their activities and audiences, that would allow them to understand better the audiences they reach and how they approach these audiences as well as the broader nature of their communication approaches. This in turn could highlight opportunities as well as gaps in their provision.

7.2 RQ2: 'How do communicators working in Botanic Gardens embody science communication within distinct cultures?'

To answer RQ2, firstly I explored how communicators working in botanic gardens understand their position as science communicators. While some study participants possess a clear understanding of science communication and identify themselves as science communicators, others hold narrower views, seeing science communication merely as instrument for science education or equating it solely with the principles of the dissemination model. By understanding how study participants view science communication, insights into the ways that science communication is integrated into the institutional landscape of botanic gardens and can better understand the approaches taken to communicating and engaging with visitors.

Secondly, I investigated the aims of the activities carried out by communicators working in botanic gardens. I identified the most common aims for practitioners in their communications were creating an engaging environment and facilitating learning. This reflects how communicators actively contribute to the educational mission of botanic gardens. By understanding what practitioners are trying to achieve, institutions can select appropriate evaluation methods, refine their engagement strategies, and ensure that activities align with their mission.

Thirdly, I analysed the roles adopted by communicators working in botanic gardens in relation to their audiences. The participants of this study typically adopt multiple roles towards their audiences, with roles such as engager and educator being prominent in the UK, and the role of translator being particularly emphasised in Portugal. Two new roles that have not been previously described in the literature were identified: the engager and the translator. Understanding the different roles communicators adopt helps to assess how science communicators prioritise their audiences.

Fourthly, I evaluate how communicators working in botanic gardens conceptualise the interaction between botanic gardens and society. The supplying conceptualisation was found to be the most common approach that practitioners employ to balance the dynamics between science and society. However, this approach can be categorised into two types: one-way communication and the two-way asymmetrical communication. The collaborative – uses a two-asymmetrical model of communication approach (Grunig and Hunt, 1984) - and participatory – uses a participatory model of communication approach (Bucchi and Trench, 2021) conceptualisations were employed less often by practitioners; these both allow for mutual understanding between botanic gardens and society, fitting more into participatory framings of science communication. By understanding the conceptualisations adopted by science communicators, it becomes possible to identify opportunities for fostering deeper public involvement and promoting shared ownership of scientific knowledge. This, in turn, can enhance the impact, inclusivity, and relevance of science communication efforts in botanic gardens.

7.3 Implications and recommendations

The findings of this thesis have implications for science communication practice within botanic gardens and science communication scholarship. Firstly, a framework for mapping science communication activities and audiences (**Figure 9**) within botanic gardens was created to provide both researchers and practitioners with a clear, structured tool to better understand, categorise, and evaluate the diverse range of engagement efforts in these institutions. For researchers, it offers a systematic basis to compare and analyse practices across different gardens and contexts, facilitating more robust and generalisable insights. For practitioners, the framework serves as a practical guide to identify gaps, plan more effective communication strategies, and tailor activities to specific audiences, ultimately enhancing the impact and inclusivity of their science communication endeavours. Moreover, it could encourage practitioners to reflect on the approaches they typically apply, while also helping to ensure that all components of their science communication practice are addressed. Furthermore, it could be adapted for similar institutions as zoological gardens.

Secondly, from the perspective of science communication scholarship, this study suggests that existing models do not fully capture the realities of science communication within botanic gardens. In response, I propose an evolved theoretical framework that better accommodates the diverse contexts in which science communication occurs. Specifically, I have reconstructed the framework (**Table 10**) to reflect non-academic settings—such as botanic gardens, and potentially zoos and other cultural institutions—by integrating a two-way asymmetrical model from public relations, here reframed as ‘involvement’, alongside with the dissemination and participatory models of science communication.

This does not imply that dialogue cannot be employed in botanic gardens, although no clear examples of true dialogue were identified in this thesis. I suggest that larger botanic gardens, particularly those engaged in research areas where lay people can contribute meaningfully—such as traditional knowledge of medicinal plants, ethnobotany, local ecological knowledge, or community-driven conservation projects—may provide opportunities for genuine two-way exchanges that shape research questions and interpretations.

7.3.1 Practitioners recommendations

- Utilise the framework to map and reflect on current communication activities, identifying gaps and opportunities to diversify and improve engagement strategies.
- Provide ongoing training and development to enable practitioners to adopt a wider range of communication approaches beyond traditional dissemination.
- Encourage larger botanic gardens and institutions engaged in relevant research areas to facilitate meaningful two-way exchanges, fostering genuine collaboration between scientists and the public. Moreover, reporting these findings in this way enables other institutions to adopt and apply these approaches in their own science communication practices.
- Specifically, for EBGC, adopt predefined categories of activities and audiences for the national reports. This approach would enable a more comprehensive and comparable overview of botanic garden initiatives across countries. It would also facilitate accurate identification and reporting of audiences and activities, ensuring greater consistency in national reports.

7.3.2. Research recommendations

- Adopt and refine the proposed framework for models of communication to guide future research, enabling more nuanced and contextually relevant analysis of science communication in non-academic settings.
- Investigate the potential and limitations of dialogue and participatory models in botanic gardens and similar institutions, especially where community knowledge and co-creation may influence scientific inquiry.
- Examine the perception of practitioner identities to better understand how terminologies affect public engagement and institutional roles.
- Promote interdisciplinary collaboration to develop frameworks that reflect the complexities of science communication across diverse cultural and natural heritage sites.

7.4 Limitations

The mixed-method methodological approach employed in this thesis sought to generate reliable and valid data pertinent to the field of science communication. It sought to offer insights valuable to both the scholarly discourse and the practices within botanic gardens. However, there were limitations that I believe can be addressed in future research.

Firstly, an initial objective was to portray the frequency of science communication activities and the target audience of these activities in European botanic gardens through analysis of the national reports. However, this was limited by a lack of quantifiable information and clarity in these documents. The data obtained by the national reports are dependent on the activities reported by botanic gardens; as well as their vision about what should be reported, or what is considered a science communication activity. Furthermore, the caveats of data (heterogeneous reporting, uneven number of reports per country, level of detail, inability to identify activities or audiences in finer detail) did not allow the depth of analysis originally anticipated. As a result, the findings were limited to the information provided in these reports. In the future this could be mitigated by providing a framework for BGCI to add to their national report templates that would support more consistent reporting.

Secondly, an attempt was made to fill the possible gaps in the identified categories with a survey which combined quantitative and qualitative data collection. However, the respondents did not fill the open-ended questions, limiting the data collected. Although the survey was sent to the representatives of botanic garden networks of each country, who are people with extensive knowledge about their country's reality, they represent only one survey per country, a limitation I am aware of. A future study could explore the activities and audiences reached directly with a larger sample of staff from individual botanic gardens within Europe.

Regarding the interviews, they information shared by participants could be influenced since some of them were conducted during COVID-19 pandemic, which affected the public engagement and outreach of botanic gardens. Furthermore, the interviews carried out after the pandemic could also be influences because botanic gardens might not yet be working in their maximum capacity.

7.5 Future directions for research

This thesis has provided valuable insights into the field of science communication and its practices within botanic gardens. By doing so, it has opened new questions and research themes that would be intriguing to explore in the future.

Firstly, it would be beneficial to uncover the frequency of activities and their target audience by country in European botanic gardens. For the UK, extending this research to other plant-based organisations with a strong component of public engagement such as Royal Parks and Royal Horticultural Society could shed new light on whether botanic gardens are missing certain opportunities or approaches. This comparative analysis could reveal gaps and potential areas for improvement, enhancing the overall effectiveness of science communication in these institutions.

Secondly, for the advancement of science communication scholarship, it would be insightful to explore how the new model proposed, which incorporates both science communication and public relations thinking about the relationships between science and society could be applied in other similar contexts. It would also be worth examining whether there are potential contributions to such a framework from environmental education or marketing which could provide a more holistic and effective approach to engaging with diverse audiences.

Thirdly, it would be valuable to explore how visitors of botanic gardens perceive their experiences in various activities and how these experiences influence their knowledge, attitudes, and behaviours towards plants and environmental issues. Such exploration can guide botanic gardens in refining their activities to better meet the needs and interests of their audiences, as well as collecting feedback from visitors. Such research may highlight areas for improvement and innovation, ensuring that botanic gardens remain dynamic and responsive to public expectations. This process will not only enhance visitor satisfaction but also strengthen the role of botanic gardens in fostering connections between people and plants. Botanic gardens would tailor their programmes to be more effective and enhancing their relevance and impact in todays' society.

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Appendices

A: Ethics material

1. Participant Information Sheet

Practices of Science Communication in Plant Diversity

You are invited to take part in research taking place at the University of the West of England, Bristol as part of PhD studies. It is funded by the Portuguese Foundation for Science and Technology, reference SFRH/BD/146474/2019. Before you decide whether to take part, it is important for you to understand why the study is being done and what it will involve. Please read the following information carefully and if you have any queries or would like more information, please contact Andreia Jorge, Faculty of Health and Applied Sciences (HAS), University of the West of England, Bristol, andreia2.jorge@live.uwe.ac.uk.

Who is organising and funding the research?

The project lead is by Andreia Jorge (PhD student). Dr Emma Weitkamp (director of studies), Dr. Hannah Little (second supervisor), Dr. Teresa Girão (second supervisor) and Dr. António Gouveia (second supervisor) are co-Investigators. The team's bios and details of their work are available at https://www.uwe.ac.uk/research/centres-and-groups/scu/members/andreia-jorge; https://www.uwe.ac.uk/research/centres-and-groups/scu/members/dr-emma-weitkamp; https://www.uwe.ac.uk/research/centres-and-groups/scu/members/hannah-little; https://www.linkedin.com/in/teresagiraodacruz?originalSubdomain=pt; https://orcid.org/0000-0002-7175-0365.

What is the aim of the research?

The research is exploring how plant diversity communication is practiced by institutions, namely botanic gardens (BG's) and plant-focused organisations (PFO's), and by staff working within these organisations.

The results of our study will be analysed and presented as a PhD thesis that will be available on the University of the West of England's open access repository. The anonymised results may also be used in conference papers and peer-reviewed academic papers.

Why have I been invited to take part?

You have been invited to participate as an expert from either a botanical garden or a client focused organisation. I am interested in gaining information about your professional experience of communicating about plant diversity, and so the interview will ask you about these things. We will not be asking any questions about personal details (e.g., gender, sexual orientation, religion, political opinions). The purpose of the questions will be to gain information about your professional experience.

Do I have to take part?

You do not have to take part in this research. It is up to you to decide whether you want to be involved. If you do decide to take part, you will be given a copy of this information sheet to keep and will be asked to sign a consent form. If you do decide to take part, you are able to withdraw from the research without giving a reason, until the point at which data analysis commences (December 2022). If you decide to withdraw from the study within this period, please write to Andreia Jorge, andreia2.jorge@live.uwe.ac.uk. Deciding not to take part or to withdraw from the study does not have any penalty.

What will happen to me if I take part and what do I have to do?

If you agree to take part, you will be asked to take part in an interview which will be conducted either online (e.g., Microsoft teams) or if appropriate in person at your place of work. You will be able to choose which style of interview you would prefer to participate in and the time for that interview. The interview will be conducted by Andreia Jorge. The team are all experienced in the subject matter and are sensitive to issues it may raise. The interview will take approximately 1h.

The subject and focus of the discussion will be your experience of communicating about plant diversity and your views on the importance of this topic. Your answers will be fully anonymised in the final PhD thesis and any associated publications.

Your interview will be recorded on a voice recorder, but the recording will not contain your name. A unique identifier code will be attribute to you to enable you to withdraw from the study within the period if you so choose. You will be offered the opportunity to check the transcription. At the point you have checked the transcription (or decided not to), your voice recording will be deleted. Your data will be anonymised at this point and will be analysed with interview data from other anonymised participants.

What are the benefits of taking part?

This work is funded to understand the practices of science communication regarding plant diversity. Even though you cannot be a direct beneficiary by participating in this study, if you take part, you will be helping us to gain a better understanding how plant diversity communication is performed. This may offer benefits to the wider community of those engaged in communicating about plant diversity. We believe the results of this project will be interesting for your profession.

What are the possible risks of taking part?

We do not foresee or anticipate any significant risk to you in taking part in this study. If, however, you feel uncomfortable at any time you can ask for the interview to stop. If you need any support during or after the interview, then the researchers will be able to put you in touch with suitable support agencies. The research team are experienced in conducting interviews and are sensitive to the subject area. The interview has been designed with these considerations in mind.

What will happen to your information?

All the information we receive from you will be treated in the strictest confidence.

All the information that you give will be kept confidential and anonymised at the point of transcription. The only circumstance where we may not be able to keep your information confidential is in a document file that has your personal code and contact information, after results publication, this file will be deleted.

All research data will be kept on a UWE OneDrive, that only the researchers will have access to in accordance with the University's policies and the Data Protection Act 2018 and General Data Protection Regulation requirements. Voice recordings will be destroyed securely once the transcription has been checked. Your anonymised data will be analysed together with other interview data, and we will ensure that there is no possibility of identification or re-identification from this point.

Where will the results of the research study be published?

A PhD thesis will be written on the basis of the data collected. This thesis will be available on the University of the West of England's open-access Research Repository. In addition, peer-reviewed academic journal articles may be produced. The project funder is the Portuguese Foundation for Science and Technology.

Who has ethically approved this research?

The project has been reviewed and approved by Health and Applied Sciences Faculty of the West of England University Research Ethics Committee. Any comments, questions or complaints about the ethical conduct of this study can be addressed to the Research Ethics Committee at the University of the West of England at: Researchethics@uwe.ac.uk

What if something goes wrong?

No risks have been identified in relation to participants in this research. However, if you have any concerns, please contact Dr Emma Weitkamp (emma.weitkamp@uwe.ac.uk) who is the Director of Studies, in the first instance.

What if I have more questions or do not understand something?

If you would like any further information about the research, in the first instance please contact:

Andreia Jorge

Email: andreia2.jorge@live.uwe.ac.uk.

Address: The Science Communication Unit, Faculty of Health and Applied Sciences, Department of Applied Sciences, University of the West of England, Frenchay Campus, Coldharbour Lane, Bristol BS16 1QY, United Kingdom.

Thank you for agreeing to take part in this study.

You will be given a copy of this Participant Information Sheet and your signed Consent Form to keep.

2. Consent Form for research participants

Practices of science communication in plant diversity

This consent form will have been given to you with the Participant Information Sheet. Please ensure that you have read and understood the information contained in the Participant Information Sheet and asked any questions before you sign this form. If you have any questions please contact a member of the research team, whose details are set out on the Participant Information Sheet.

If you are happy to take part in the interview, please sign and date the form. You will be given a copy to keep for your records.

- I have read and understood the information in the Participant Information Sheet which I have been given to read before being asked to sign this form;
- I have been given the opportunity to ask questions about the study;
- I have had my questions answered satisfactorily by the research team;
- I agree that anonymised quotes may be used in the final PhD thesis, and any associated academic publications, and report to funder of this study;
- I understand that my participation is voluntary and that I am free to withdraw at any time until the data have been analysed (December 2022), without giving a reason;
- I agree to take part in the research

Name (Printed)…….

Signature……. Date…….

3. Privacy Notice for Research Participants – Practices of Science Communication in Plant Diversity

Purpose of the Privacy Notice

This privacy notice explains how the University of the West of England, Bristol (UWE Bristol) collects, manages and uses your personal data before, during and after you participate in **the interview**. 'Personal data' means any information relating to an identified or identifiable natural person (the data subject).

This privacy notice adheres to the General Data Protection Regulation (GDPR) principle of transparency. This means it gives information about:

- How and why your data will be used for the research;
- What your rights are under GDPR; and
- How to contact UWE Bristol and the project lead in relation to questions, concerns or exercising your rights regarding the use of your personal data.

This Privacy Notice should be read in conjunction with the Participant Information Sheet and Ethical Consent Form provided to you before you agree to take part in the research.

Why are we processing your personal data?

UWE Bristol undertakes research under its public function to provide research for the benefit of society. As a data controller we are committed to protecting the privacy and security of your personal data in accordance with the (EU) 2016/679 the General Data Protection Regulation (GDPR), the Data Protection Act 2018 (or any successor legislation) and any other legislation directly relating to privacy laws that apply (together "the Data Protection Legislation"). General information on Data Protection law is available from the Information Commissioner's Office (https://ico.org.uk/).

How do we use your personal data?

We will only process your personal data when the law allows us to. In addition, we will always comply with UWE Bristol's policies and procedures in processing your personal data. Our lawful basis for using your personal data for research purposes is fulfilling tasks in the public interest, and for archiving purposes in the public interest, for scientific or historical research purposes. -

We will always tell you about the information we wish to collect from you and how we will use it. We will not use your personal data for automated decision making about you or for profiling purposes.

Our research is governed by robust policies and procedures and, where human participants are involved, is subject to ethical approval from either UWE Bristol's Faculty or University Research Ethics Committees. This research has been approved by **HAS Research Ethics Committee (FREC), ethics application number (to be inserted), contact researchethics@uwe.ac.uk for queries, comments or complaints.**

The research team adhere to the principles of the General Data Protection Regulation (GDPR).

For more information about UWE Bristol's research ethics approval process please see our Research Ethics webpages at www1.uwe.ac.uk/research/researchethics

What data do we collect?

The data we collect will vary from project to project. Researchers will only collect data that is essential for their project. The specific categories of personal data processed are described in the Participant Information Sheet provided to you with this Privacy Notice. ***The categories of personal data will be the name, place of work, and occupation. The interview questions are about your professional experience.***

Who do we share your data with?

We will only share your personal data in accordance with the attached Participant Information Sheet. ***There is no intention to share personal data with third parties, as well as data processing.***

How do we keep your data secure?

We take a robust approach to protecting your information with secure electronic and physical storage areas for research data with controlled access. Access to your personal data is strictly controlled on a need to know basis and data is stored and transmitted securely using methods such as encryption and access controls for physical records where appropriate.

Alongside these technical measures there are comprehensive and effective policies and processes in place to ensure that those who process your personal information (such as researchers, relevant University administrators and/or third-party processors) are aware of their obligations and responsibilities for the data they have access to.

By default, people are only granted access to the information they require to perform their duties. Mandatory data protection and information security training is provided to staff and expert advice available if needed.

How long do we keep your data for?

Your personal data will only be retained for as long as is necessary to fulfil the cited purpose of the research. The length of time we keep your personal data will depend on several factors including the significance of the data, funder requirements, and the nature of the study. Specific details are provided in the attached Participant Information Sheet. ***Audio recordings will be deleted after data transcription and checking, participant identification code list will be deleted after data publication, processed data will be deleted 2 years after thesis delivery.***

Anonymised data that falls outside the scope of data protection legislation as it contains no identifying or identifiable information may be stored in UWE Bristol's research data archive or another carefully selected appropriate data archive.

Your Rights and how to exercise them

Under the Data Protection legislation, you have the following **qualified** rights:

1. The right to access your personal data held by or on behalf of the University;
2. The right to rectification if the information is inaccurate or incomplete;
3. The right to restrict processing and/or erasure of your personal data;
4. The right to data portability;
5. The right to object to processing;
6. The right to object to automated decision making and profiling;
7. The right to complain to the Information Commissioner's Office (ICO).

We will always respond to concerns or queries you may have. If you wish to exercise your rights or have any other general data protection queries, please contact UWE Bristol's Data Protection Officer (dataprotection@uwe.ac.uk).

If you have any complaints or queries relating to the research in which you are taking part please contact either the research project lead, whose details are in the attached Participant Information Sheet or UWE Bristol's research governance manager (researchgovernance@uwe.ac.uk.).
v.2: This template Privacy Notice was last amended in November 2020 and will be subject to regular review/update.

3. BGCI Data Supply Agreement

This appendix has been removed as it contains personal information.

B: Research material

1. Survey

These are screenshots of the survey.

Default Question Block

1. Please, select the country you represent:

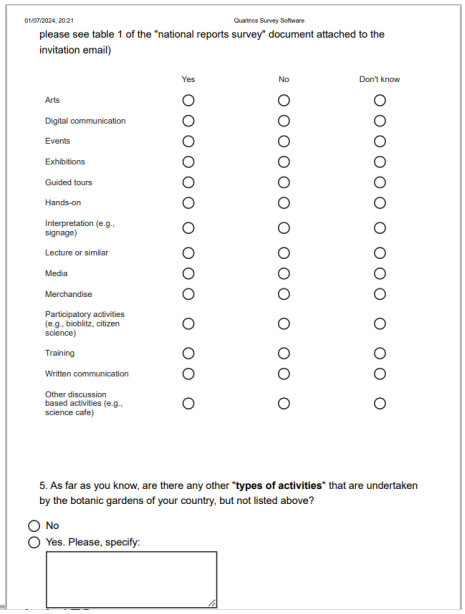
2. If above you selected "Other", please specify:

3. Have you contributed to the National Reports in the last 3 years?

- Yes
- No
- Don't know

4. As far as you know, are the following "**types of activities**" undertaken by the botanic gardens of your country?

(For a more detailed explanation of the "types of activities" definitions and examples,

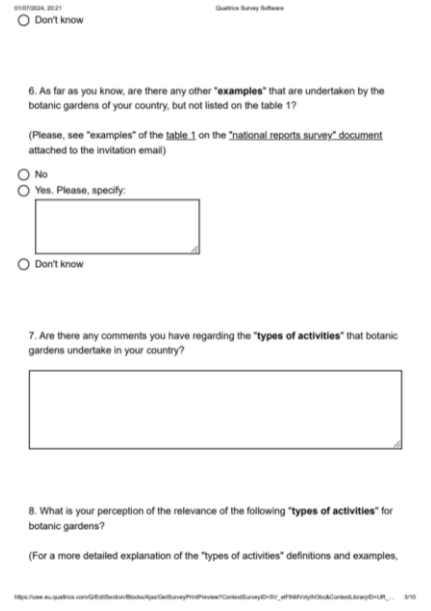


please see table 1 of the "national reports survey" document attached to the invitation email)

	Yes	No	Don't know
Arts	○	○	○
Digital communication	○	○	○
Events	○	○	○
Exhibitions	○	○	○
Guided tours	○	○	○
Hands-on	○	○	○
Interpretation (e.g., signage)	○	○	○
Lecture or similar	○	○	○
Media	○	○	○
Merchandise	○	○	○
Participatory activities (e.g., bioblitz, citizen science)	○	○	○
Training	○	○	○
Written communication	○	○	○
Other discussion based activities (e.g., science cafe)	○	○	○

5. As far as you know, are there any other "**types of activities**" that are undertaken by the botanic gardens of your country, but not listed above?

- No
- Yes. Please, specify:



- Don't know

6. As far as you know, are there any other "**examples**" that are undertaken by the botanic gardens of your country, but not listed on the table 1?

(Please, see "examples" of the table 1 on the "national reports survey" document attached to the invitation email)

- No
- Yes. Please, specify:
- Don't know

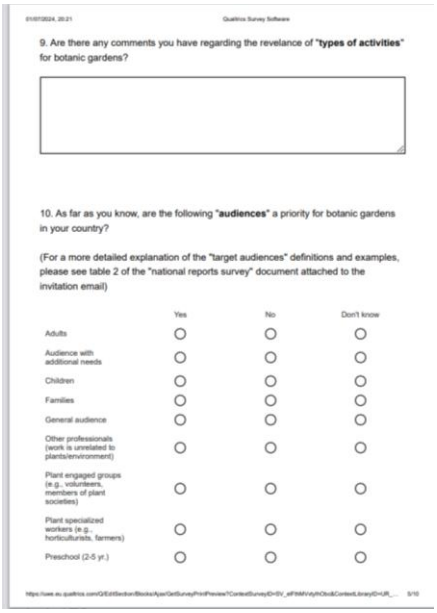
7. Are there any comments you have regarding the "**types of activities**" that botanic gardens undertake in your country?

8. What is your perception of the relevance of the following "**types of activities**" for botanic gardens?

(For a more detailed explanation of the "types of activities" definitions and examples,

please see table 1 of the "national reports survey" document attached to the invitation email)

	Very relevant	Relevant	Neutral	Low relevant	Not relevant
Arts	○	○	○	○	○
Digital communication	○	○	○	○	○
Events	○	○	○	○	○
Exhibitions	○	○	○	○	○
Guided tours	○	○	○	○	○
Hands-on	○	○	○	○	○
Interpretation (e.g., signage)	○	○	○	○	○
Lecture or similar	○	○	○	○	○
Media	○	○	○	○	○
Merchandise	○	○	○	○	○
Participatory activities (e.g., bioblitz, citizen science)	○	○	○	○	○
Training	○	○	○	○	○
Written communication	○	○	○	○	○
Other discussion based activities (e.g., science cafe)	○	○	○	○	○
Other. Please, specify:	○	○	○	○	○
Other. Please, specify:	○	○	○	○	○
Other. Please, specify:	○	○	○	○	○

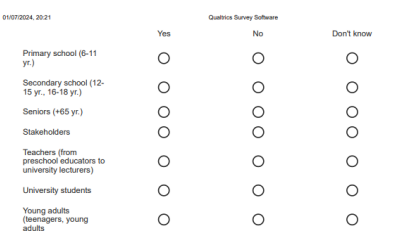


9. Are there any comments you have regarding the revelance of "**types of activities**" for botanic gardens?

10. As far as you know, are the following "**audiences**" a priority for botanic gardens in your country?

(For a more detailed explanation of the "target audiences" definitions and examples, please see table 2 of the "national reports survey" document attached to the invitation email)

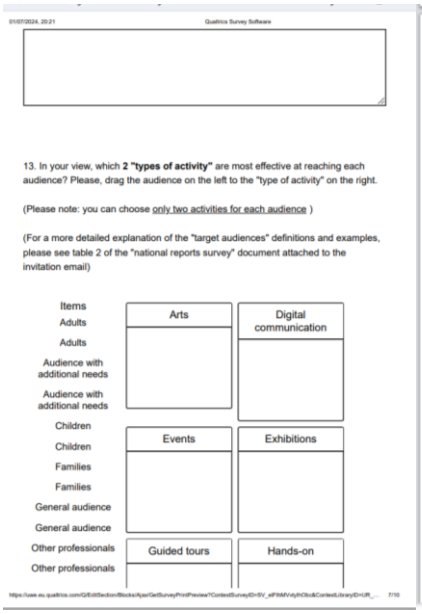
	Yes	No	Don't know
Adults	○	○	○
Audience with additional needs	○	○	○
Children	○	○	○
Families	○	○	○
General audience	○	○	○
Other professionals (work is unrelated to plants/environment)	○	○	○
Plant engaged groups (e.g., volunteers, members of plant societies)	○	○	○
Plant specialized workers (e.g., horticulturists, farmers)	○	○	○
Preschool (2-5 yr.)	○	○	○



	Yes	No	Don't know
Primary school (6-11 yr.)	○	○	○
Secondary school (12-15 yr., 16-18 yr.)	○	○	○
Seniors (+65 yr.)	○	○	○
Stakeholders	○	○	○
Teachers (from preschool educators to university lecturers)	○	○	○
University students	○	○	○
Young adults (teenagers, young adults	○	○	○

11. Please, list any "**target audiences**" that are missing from the choices in question 10 (above):

12. Please, add any comments you may have regarding the ways in which botanic gardens in your country choose activities for specific audiences:

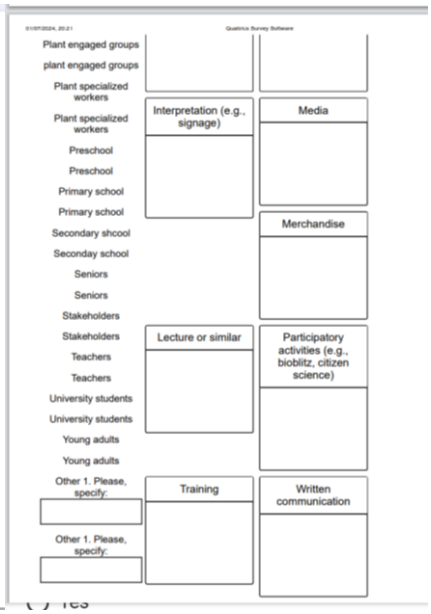


13. In your view, which **2 "types of activity"** are most effective at reaching each audience? Please, drag the audience on the left to the "type of activity" on the right.

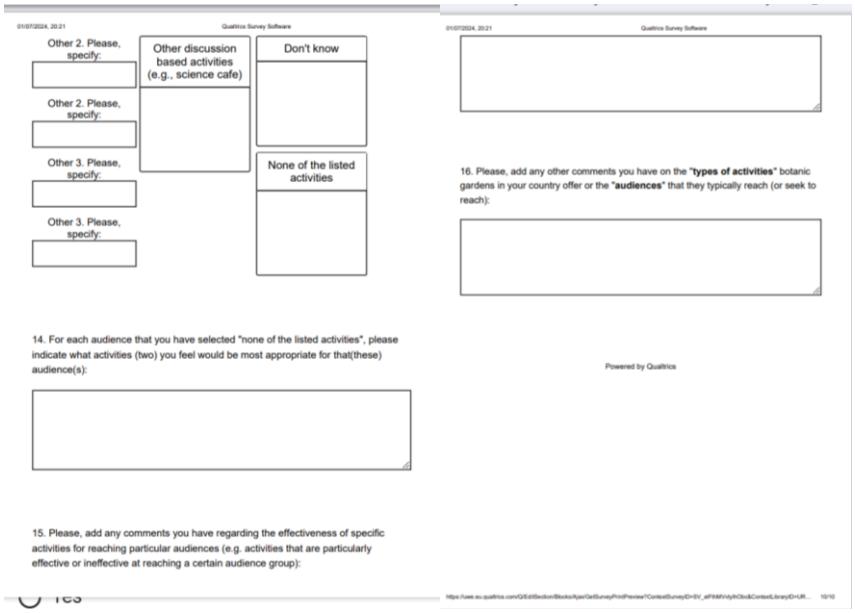
(Please note: you can choose only two activities for each audience)

(For a more detailed explanation of the "target audiences" definitions and examples, please see table 2 of the "national reports survey" document attached to the invitation email)

Items	Arts	Digital communication
Adults Adults Audience with additional needs Audience with additional needs		
	Events	**Exhibitions**
Children Children Families Families General audience General audience		
	Guided tours	**Hands-on**
Other professionals Other professionals		



Plant engaged groups plant engaged groups		
Plant specialized workers Plant specialized workers	**Interpretation (e.g., signage)**	**Media**
Preschool Preschool Primary school Primary school		
Secondary shcool Seconday school Seniors Seniors		**Merchandise**
Stakeholders Stakeholders Teachers Teachers University students University students	**Lecture or similar**	**Participatory activities (e.g., bioblitz, citizen science)**
Young adults Young adults		
Other 1. Please, specify: Other 1. Please, specify:	**Training**	**Written communication**



2. Interviews

Interview framework
Can you briefly describe your functions in your place of work?
What is your qualification/educational background?
Did you attend any workshops, training, or conferences about science communication? If yes, how do you feel they contribute to your work?
How would you explain what a science communicator does?
What are your aims when you communicate with the public?
How do you plan communication activities?
What practices/activities do you employ in your work? What type of practices/activities do you think engage the public best? Why?

Can you talk about one of the activities you most enjoyed doing? Which type of activity do you like more to do? Why? What were your roles/responsibilities in that activity?
Could you describe one science communication activity and what the public do during this activity? Are other activities where the audience participate in different ways? If so, could you describe how they participate?
There is evaluation for the activities? If yes, how are accessed the impact of the activities with public? There is any barrier?
What challenges do you face when you communicate with the public?
Have you ever found yourself in a situation where you didn't know the answer to a question asked by the audience? If yes, how do you deal?
Who are the people you try to reach in your communication activities?
What is your perception about the relevance of your job within society?
What is the best way to develop science communication in a botanic garden?
To which extent do you think the public can contribute to the work in botanic gardens? Can you through an example? And to research work?
Who do you think should deliver science communication activities to the public, science communicators, scientists, or both? Could you explain your thought?
What makes you passionate about being a science communicator/educator?
What science communication and science education means to you?
What are the missions of your botanic garden?

What a botanic garden may offer/benefit to a member of public or society? And policymakers and stakeholders (e.g., cities councils, NGOs)? What is the role of your botanic garden for society?