Public engagement with science –

Breaking the hegemony and shifting paradigms

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To my family and friends who have supported me and encouraged me throughout, most especially my husband, Silvan and my son, Nikol.

ABSTRACT

Danielle Martine Farrugia

Public engagement with science – Breaking the hegemony and shifting paradigms

The study adopted a mixed-method approach to understand the public engagement with science (PES) landscape in the Maltese Islands. The study is significant as it sheds light on the systemic pattern throughout society by understanding the role of entities conducting PES in reproducing exclusionary citizens' lack of participation in science. The study adopts a critical lens using Habermas's public sphere applied to science and Bourdieu's lens of the capital.

The research involved a scoping literature review of international documents mentioning PES. Two questionnaires were created - one to gather insights from Maltese residents over 18 about science and their participation in science activities, and another for members of public engagement with science networks (PENs) to understand their engagement with the PENs. In addition, interviews were conducted with senior management of major entities involved in PES in the Maltese Islands and senior management of PENs. The study found that Maltese residents are generally highly interested in science. Furthermore, individuals with higher levels of education tend to participate in science-related activities more actively, while those with primary or secondary education exhibit relatively lower levels of engagement. The study revealed that international PEN members generally contribute more to the PEN in terms of time, knowledge, stakeholder contacts, mentoring, and proposal writing rather than financially to the network. However, respondents tend not to join other PENs due to high membership fees and lack of information. The study discusses the power dynamics involved in accessing science within the Maltese public sphere of science (PSS). It highlights that stakeholders at the centre who have gained enough social capital have the most authority, while publics on the outskirts have minimal power. Certain publics on the outskirts can gain more influence and access higher levels if the conditions are favourable.

The study suggests that a national PES space could improve communication between science communication practitioners and researchers. A national strategy for PES could potentially establish appropriate governance and policy for citizens' critical engagement and involvement at various levels of PES in the PSS. The study emphasises the importance of a systemic shift towards citizens' critical engagement and participation by entities conducting PES to break hegemony and change paradigms. The findings emphasise the need for more inclusive and accessible PES initiatives and the importance of addressing power dynamics in science communication and engagement.

Keywords: Public engagement with science, public sphere of science, professional networks, capital of science, science communication

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List of Abbreviations

Actor-network theory (ANT)

Artificial intelligence (AI)

Alliance for a Media Literature (AMLA)

American Association for the Advancement of Science (AAAS)

Annual general meeting (AGM)

Association of Communicators in Education and Science (AKSON)

Association of Science and Technology Centres (ASTC)

Australian Citizen Science Association (ACSA)

Australian National Centre for the Public Awareness of Science (CPAS)

Bovine spongiform encephalopathy (BSE)

Business for Social Responsibility (BSR)

Business, Innovation and Skills (BIS)

Chinese Citizen Science Association (CCSN).

Citizen Science Association (CSA)

Committee for Research Engagement (CRE)

Continuous professional development (CPD)

Coronavirus disease 2019 (COVID-19)

Corporate social responsibility (CSR)

Council for Science, Technology, and Innovation (CSTI)

Directorate for Learning and Assessment Programmes (DLAP)

Education officers (EOs)

European Centre for the Development of Vocational Training (Cedefop)

European Citizen Science Association (ECSA)

European Citizen Science Association Network (ECSA)

European Commission (EC)

European Federation for Science Journalism (EFSJ)

European Network of Science Centres and Museums (Ecsite)

European Research Area (ERA)

European Researchers' Night (ERN)

European Science Engagement Association (EUSEA)

European Union (EU)

Evidence-Based Science Communication (EBSC)

Findable, accessible, interoperable, and reusable terms (FAIR)

Foundation for Environmental Education (FEE)

General data protection regulation (GDPR)

Gross domestic product (GDP)

Gross expenditure on research & development (GERD)

Human immunodeficiency virus (HIV)

Information and communication technology (ICT)

Institute of Electrical and Electronics Engineers (IEEE)

International Association for the Evaluation of Educational Achievement (IEA)

International Consortium of Research Staff Associations (ICoRSa)

Key Impact Pathways (KIP)

Lesbian, Gay, Bisexual, Transgender, Queer (LGBTQ+)

Malta Chamber of Scientists (MCS)

Malta College for Arts, Science and Technology (MCAST)

Malta Council for Science and Technology (MCST)

Malta Qualifications Framework (MQF)

Market Intelligence Services Company Limited (MISCO)

Matriculation and Secondary Education Certificate (MATSEC)

Members of the European Parliament (MEPs)

Ministry for Education, Sport, Youth, Research, and Innovation (MEYR)

Ministry of Education, Culture, Sports, Sciences and Technology (MEXT)

National Coordinating Centre for Public Engagement (NCCPE)

National Curriculum Framework (NCF)

National Open Research Form (NORF)

Network administrative models (NAO)

Network for the popularisation of science and technology in Latin America and the Caribbean (Redpop)

Non-governmental organisation (NGO)

Organisation for Economic Co-operation and Development (OECD)

Popularisation of Science and Technology (PST)

Pre-learning activity (PLA)

Programme for International Student Assessment (PISA)

Public Communication with Science and Technology (PCST)

Public engagement (PE)

Public engagement with science Networks (PENs)

Public engagement with science (PES)

Public engagement with science and technology (PEST)

Public relations (PR)

Public sphere of science (PSS)

Public understanding of science (PUS)

Research and development (R&D)

Research and innovation (R&I)

Research Innovation and Development Trust (RIDT).

Research, Science and Innovation (RSI)

Responsible Research and Innovation (RRI)

Responsible research and innovation globally (RRING).

Science Communicators Association of New Zealand (SCANZ).

Science in the City (SITC)

Science with and for Society (SwafS)

Science, Technology, and Innovation (STI)

Science, Technology, Engineering and Mathematics (STEM)

Science, Technology, Engineering, Arts, and Mathematics (STEAM)

Sociology of scientific knowledge (SSK)

Sustainable development goals (SDGs)

Trends in International Mathematics and Science Study (TIMSS)

United Kingdom (UK)

United Nations Convention on the Rights of the Child (UNRC)

United Nations Educational, Scientific and Cultural Organisation (UNESCO)

United Nations Framework Convention on Climate Change (UNFCC)

United States (US)

University of Malta (UM)

Vocational and education training (VET)

World Health Organisation (WHO)

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Preface

Embarking on my PhD journey in public engagement with science and technology is the culmination of a path enriched by diverse experiences, fervent curiosity, and a commitment to bridging the gap between education, research, and communication. My journey began in education, where I taught science and physics to 11-15-year-olds at the secondary school level. After graduating from the Faculty of Education at the University of Malta, I became increasingly intrigued by how older citizens engage with science and technology. I delved deeper into what happens after formal education has ceased, realising that the impact of science communication extends far beyond formal education. It encompasses the participation of citizens, stakeholders, and diverse publics with science and technology, driving innovation, societal progress, and informed decision-making.

This led to me studying science communication further through a Masters in Science and Society at the Open University. My dedication to advancing science engagement and discourse extends beyond the classroom and into the public sphere. As the project manager of Malta Café Scientifique, I facilitate thought-provoking dialogues and interactive sessions that bring together researchers, citizens, and stakeholders to explore cutting-edge scientific topics and their theoretical and practical applications in a relaxed and informal setting. These events serve as catalysts for dialogue and collaboration, fostering a culture of scientific curiosity and engagement within the community. With the media being one of the ways that citizens access scientific information, I founded a science programme, Radio Mocha Malta, on the national local radio station. I also assist researchers and science practitioners in communicating their work on the Sounds of Science page, published weekly in the Sunday Times of Malta. It was during this period that I ventured to focus my professional work on engaging citizens with science in the informal sector. I worked as a research support officer on an EU project with the Faculty of Science at the University of Malta and managed the communication of hybrid optomechanical technologies to various audiences, from creating videos aimed towards young audiences to interactive light installations during science festivals, talks, educational apps, and others. It was also during this period that I was intrigued to start my doctoral studies in this area to map the science communication landscape in the Maltese islands. Now, as a senior executive with the Communications Office at the University of Malta, I am committed to engaging and empowering individuals of all ages to become active participants in the production of scientific knowledge. I spearheaded the Unconventional Science Careers project to engage 11/12-year-olds to visit the Science, Technology, Engineering, and Mathematics (STEM) faculties at UM and engage with researchers about the different aspects of STEM incorporating the arts and using the STEAM approach. As a staunch advocate for gender equality in STEM, I spearheaded initiatives aimed at amplifying the voices of women in scientific research and promoting inclusivity within the scientific community. I have organised special events and moderated sessions at international conferences, each endeavour driven by a fervent belief in the power of diversity to propel scientific progress forward. With each endeavour, I am driven by a singular purpose: to inspire curiosity, foster understanding, and empower individuals to become active participants in the dynamic world of science. I hope that as you read this, you will find my doctoral research in science communication in Malta interesting. My research aims to explore the informal aspect of the Maltese islands' public sphere of science and the relationship between the different stakeholders and publics in terms of their engagement with science. I believe that my study provides valuable insights into the dynamics of science communication in Malta.

Chapter 1

Introduction:

Exploring the dynamic landscape of public engagement with science

1.1 What is science?

Science is a multifaceted approach to understanding the world, encompassing a body of knowledge consisting of facts, concepts, principles, laws, and scientific methods and techniques (Chalmers, 2013). Moreover, science is a set of attitudes and values that shape the scientific community's knowledge acquisition and dissemination approach. Over time, the concept of science has evolved significantly, from the empiricism of Bacon to the falsifiability criterion of Popper to the paradigm shifts of Kuhn and the methodological anarchism of Feyerabend (Gaukroger, 2001). These developments have contributed to the refinement and improvement of scientific methods and techniques and the understanding of the nature of science itself.

During the mid-1950s, the scientific philosophies of empiricism, inductivism, and logical positivism were widely accepted. Empiricism and positivism both view scientific knowledge as something derived from facts through observation (Chalmers, 2013). Science can be seen as an inductive process through unbiased observations that the observer records as singular statements. These are then justified through a person's unprejudiced senses and, after many observations, come up with a universal statement (Gaukroger, 2001). Conversely, David Hume stated that it is impossible to justify a scientific law by observation or experimentation (Buckle, 2004). Furthermore, evidence from the history of science lacks support towards the inductivist approach (Chalmers, 2013).

However, notable figures such as Popper, Kuhn, and Polanyi had distanced themselves from these dominant philosophies (Nye, 2011). Their rejection of philosophical traditions that employed empiricism to distinguish the sciences from other fields, such as the arts, religion, metaphysics, and ideology, was a significant departure from the status quo. Karl Popper believed that scientific progress is driven by the continual testing and attempted falsification of theories (Nye, 2011; Popper, 2002). Emphasis was placed on the importance of bold conjectures that are followed by rigorous attempts to falsify them such that the strength of a scientific theory lies in how well it withstands attempts at falsification rather than confirmation through evidence (Chalmers, 2013; Nye, 2011). This created a shift in attempting to disprove theories rather than proving them, laying the groundwork for critical rationalism. Kuhn's seminal work (see Table 1.1) challenged the notion of science as purely objective and value-free and can be summarised through the following: pre-science, normal science, crisis, revolution and new normal (Chalmers, 2013; Nye, 2011; Kuhn, 1970).

Table 1.1:

Kuhn's phases of scientific knowledge production

Phase	Explanation
Pre-science	Various schools of thought compete by offering different interpretations of phenomena. Over time, one school of thought gains dominance, and the others gradually lose relevance. This phase comes to an end when a new paradigm is established, marking a shift in the prevailing understanding of the subject.
Normal science	While a paradigm must be better than its competitors, it need not explain all the facts. This phase is characterised by fact collection, and apparata are invented. The facts can be compared directly to the predictions of the paradigm and developed to lead to scientific laws.
Crisis	The research in this phase is similar to the pre-science phase. This phase ends when normal science can resolve the crisis; the problem is set aside for future generations to solve upon the invention of better tools or an emerging paradigm and the ensuing battle over its acceptance.
Revolution	This phase signifies a paradigm shift. Growth in science is not cumulative.
New normal	This phase allows for the further development of the esoteric details of a theory, solving puzzles, and conducting research guided by accepted theories and methodologies until the cycle of crisis and revolution begins again.

1.1.1 The epistemology of science – Proving or disproving science?

Both Imre Lakatos and Paul Feyerabend, prominent philosophers of science, were deeply influenced by Popper's ideas. However, they were critical of Popper's account of what constitutes science, which they viewed as overly simplistic and unable to fully capture the complexity of scientific practice (Lakatos & Feyerabend, 1999). In their work, Lakatos and Feyerabend sought to develop more nuanced and comprehensive frameworks for understanding the nature of scientific inquiry. Lakatos argued the role of progressive and degenerative shifts in moulding the evolution of scientific knowledge (Chalmers, 2013; Nye, 2011; Lakatos & Feyerabend, 1999). Conversely, Feyerabend rejected having a universal scientific method and advocated for theories and methodologies that are not necessarily from scientific domains that are accompanied by a non-linear progression characterised by periods of revolution and upheaval (Lakatos & Feyerabend, 1999). Feyeraband argued that a free society is composed of equal rights and access to the centres of power (Nye, 2011).

To maintain consistency and clarity throughout this study, it is imperative to establish a concise definition of science after deliberating on the criticisms and alternative perspectives presented by numerous philosophers of science. Therefore, I am proposing a definition of science that has been formulated and will be utilised accordingly.

> *Science tries to understand and explain the physical and natural world through deductive and inductive reasoning, observation and experimentation, and formulation of hypotheses and laws set in a multicultural context, sometimes driven by curiosity or need.*

1.2 Scientific research and its implications

1.2.1 Role of scientific research in countries

Various reasons are identified for conducting scientific research: contributing to the country's economy, being able to respond to health challenges, and creating jobs, (Gascoigne & Schiele, 2020; American Academy of Arts & Sciences, 2018; Davies & Horst, 2016; Department for Business Innovation & Skills, 2011) or simply quenching one's curiosity.

In today's knowledge-based economy, countries strive to stay relevant by staying at the forefront of new scientific and technological advancements (Abramo & D'Angelo, 2018). External economic control is increasingly influencing fields like medicine, genetics, and military research, making the line between fundamental and applied research more blurred due to their profitability (Nye, 2011). The Responsible Research and Innovation (RRI) framework, developed by the European commission (EC), lies at the heart of how scientific research is conducted, for what purpose, and who should be involved. Since its inception, RRI has evolved (Owen et al., 2021). Initially, it was described as a set of values that emphasised the involvement of all societal actors in research and innovation while keeping societal needs at the forefront (European Commission Directorate-General for Research and Innovation, 2014). The research process involves various stages, and ethical questions about when and how society should be involved still remain (Schomberg, 2013). The latest definition by the EC states that RRI is "an approach that anticipates and assesses potential implications and societal expectations concerning research and innovation, intending to foster the design of inclusive and sustainable research and innovation" (EC, 2020, Dec 7).

The RRI framework focuses on the so-called 'pillars' or five thematic elements: public engagement, open access, gender, ethics, and science education (EC, 2020, Dec 7).

- *Public engagement* brings together researchers, policy makers, industry, civil society organisations and non-governmental organisations (NGOs), and citizens to discuss issues revolving around science and technology.
- *Open access* provides free access to scholarly information for readers, but researchers bear the cost of publication fees.

- The thematic element concerning *gender* promotes equal economic independence for all genders to close the gender pay gap, advance gender balance in decision-making and stop gender-based violence.
- The *ethical* theme promotes integrity in research and innovation processes. In the science education theme, the idea was to make science careers attractive for young people inherently improving society's scientific literacy.

In addressing the implementation of the RRI framework, Stilgoe et al. (2013) explore four process dimensions to ensure that research and innovation is conducted in a responsible manner: anticipation, reflexivity, inclusion, and responsiveness (Stilgoe et al., 2013).

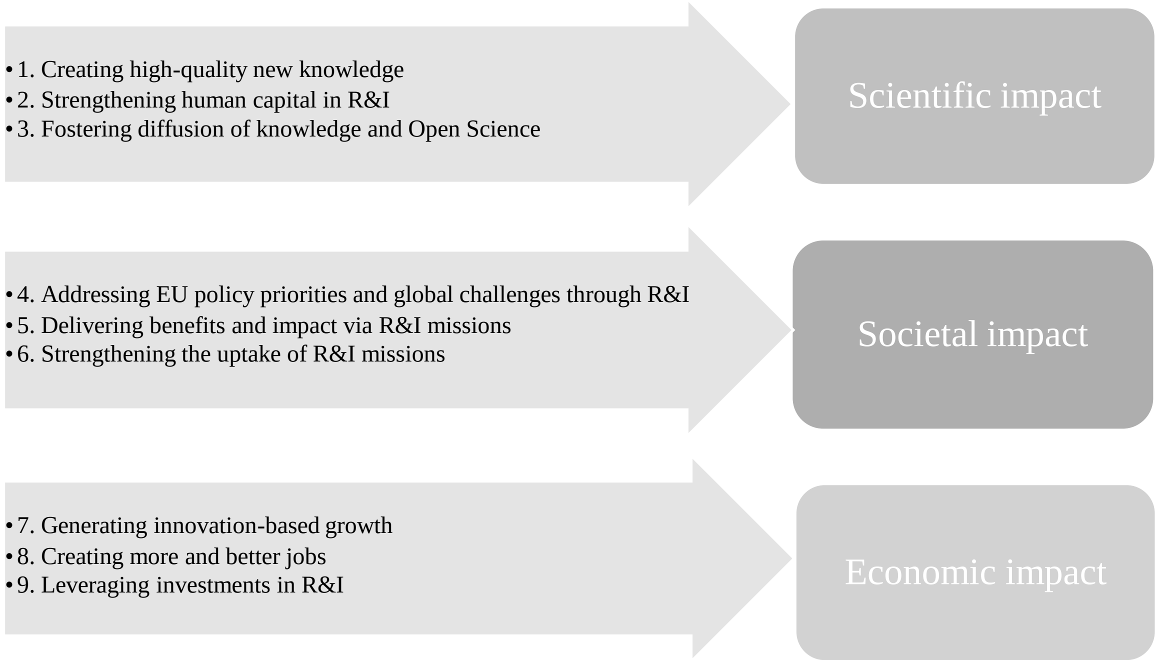
- The *anticipation* dimension includes a variety of stakeholders, such as researchers and policymakers, to precede issues when developing science and technology (Macnaghten, 2020; Stilgoe et al., 2013).
- When practising science, *reflexivity* requires institutions, scientists, and researchers to innovate responsibly.
- The *inclusion* dimension incorporates the importance of involving a wide variety of stakeholders rather than one-way communication.
- *Responsiveness* ensures that research is responsive to stakeholders' and societal needs (Macnaghten, 2020; Stilgoe et al., 2013).

The RRI framework was developed in Europe, and the interpretation of RRI in countries outside Europe is different. When innovating responsibly, a country's specific cultural and societal values and needs must be included (Ludwig & Macnaghten, 2020).

Although the RRI framework may no longer be a prominent feature of the Horizon Europe funding programme, the initiative has introduced a set of new key impact pathways (KIP) (see Figure 1.1) to guide Europe's efforts in advancing scientific excellence, tackling global issues, promoting innovation, and elevating the appeal of the European research area (ERA) (EC, 2023). This is achieved by encouraging excellence-based participation, facilitating collaborative links in research and innovation across Europe by facilitating technological development, transfer and strengthening deployment and exploitation of innovative solutions (EC, 2023).

Figure 1.1:

Horizon Europe key impact pathways



1.2.2 Science communication and engagement

Numerous historical records exist that document the occurrence of science communication events. One such example is the Royal Society's Christmas lectures, which have been open to the ‘public’ since Faraday delivered the first lecture in 1825 in the United Kingdom (Bowater & Yeoman, 2013). Another illustration is the highly recognised popular science books, such as 'L'Astronomie des Dames' (Bucchi, 2008). Science communication, also known as science vulgarisation or popularisation (Bucchi, 2008), saw significant growth in the 19th century, although its expression varies by country (Gascoigne & Schiele, 2020). While the terms popularisation and science communication are often used interchangeably, popularisation primarily focuses on the deficit model of engagement, as opposed to the participatory model of citizen engagement. After World War II, governments became increasingly interested in science communication and science itself to a better future (Gascoigne & Schiele, 2020; Gregory & Miller, 1998). Modern science communication has evolved into a field of study, a body of practice, and a profession over the past six decades (Gascoigne & Metcalfe, 2017).

After World War II, governments worldwide began emphasising the importance of science and technology and its impact on society (Gascoigne & Schiele, 2020). Countries like the United Kingdom (UK) and France invested in science communication efforts such as science museums, science weeks, and university training. Meanwhile, Germany took a more passive role, leaving it up to external organisations to lead the charge (Gascoigne & Schiele, 2020). While governments generally aim to promote scientific knowledge among their citizens, there have been instances where communication was discouraged, such as the Canadian government's discouragement of climate change discussion or

South Africa's state control and censorship during the apartheid years (Gascoigne & Schiele, 2020). This suggests that the government's need to communicate science may not always align with the citizens' needs. Macnaghten (2020) points out that during World War II, scientific research and technological development were primarily focused on achieving victory, with the needs of citizens taking a backseat. The top priorities were development and commercialisation, while issues such as food scarcity received comparatively less attention. Therefore, stakeholders were left to navigate how to communicate science and technology to fit in with government requirements.

Various media platforms have served and have been used to facilitate communication between scientists, researchers, doctors, and citizens, traditionally with the assistance of journalists. Once citizens' compulsory education ends, their science information mainly comes through television, newspapers, magazines, and the internet (Bucchi, 1998; Dunwoody, 2008).

In the latter part of the 19th century, scientists viewed popularisation as part of their job. This changed during the 20th century as scientists were seen to specialise further in their respective fields, leaving no time to communicate with citizens (Dunwoody, 2008). Science popularisation was seen as a potential way of derailing or ruining a scientist's career, although it has increased in popularity with scientists once again (Dunwoody, 2008). However, just making science popular tends to emphasise a linear mode of communication.

Through evidence-based communication, there is a need to know and understand citizens' perceptions to communicate with society effectively - and, in the case of Coronavirus disease 2019 (COVID-19), save their lives (Farrugia, 2020). Jensen and Gerber (2020) have come up with 12 points towards evidence-based science Communication (EBSC) (see Table 1.2). These include evidence-based practice, research, assessing impact, bridging the chasm, mutual appreciation and collaboration, transferability, recognising applicability, revisit the raison d'être for science communication, systematic reviews, and change, and finally, certification (Jensen & Gerber, 2020).

Table 1.2:

12 points towards EBSC

12 points towards EBSC	Explanation
1. Evidence-based practice	Increase the systematic use of evidence in science communication practice to maximise effectiveness and forestall negative impacts.
2. Evidence-based research	Reduce questionable science communication research practices, avoid preventable methodological shortcomings and increase transparency.
3. Assessing impact	Make impact evaluation of science communication a standard expectation in communication and engagement funding with the aim of refining practices based on findings.

4. Bridging the chasm	Address the divides between research and practice in science communication along the entire Knowledge Cascade to enable an integrated, evidence-based practice.
5. Mutual appreciation and collaboration	Develop initiatives to encourage both researchers and practitioners to develop mutual understanding about their needs, experiences and unique capabilities and forms of expertise.
6. Effective exchange mechanisms	Establish more effective mechanisms for exchange that work for practitioners and researchers that transcend the limitations of scholarly publishing.
7. Recognising applicability	Where research results and theory can be tested in real world situations, both research and practice need incentives to engage and collaborate. More applied, or at least practice-relevant, research also requires a more systematic analysis of the needs for research from the perspective of science communication practice.
8. Collaboration	Instead of trying to merely transfer abstract expert knowledge into practice, the science communication field needs more transdisciplinary means of collaboratively investigating and optimising science communication from within. This means using real-world data to develop both research and practice through the same initiatives without compromising quality standards on either side.
9. Revisit the raison d'être for science communication	Promote important societal values such as social inclusion, good ethical practices and democratic participation through the design of science communication initiatives.
10. Systematic reviews	Produce practical guidelines to effectively inform and orient practice by distilling the best available evidence in a methodologically robust way. This should also foster replicability and replication for key topics by making methodological transparency the norm.
11. Systemic change	Encourage informed decision-making in selecting science communication approaches for particular settings and circumstances, backed up by funding review processes that insist on evidence-informed approaches.
12. Certification	Encourage the next generation of leaders in evidence-based science communication through certification processes and standards in teaching and training.

1.3 Evolution of science education and communication

1.3.1 Formal, informal, and non-formal science education

The definition of formal learning is widely accepted as a structured and organised approach that follows a set of learning objectives (Werquin, 2010). This type of learning is intentional from the learner's perspective and leads to validation and certification (European Centre for the Development of Vocational Training (Cedefop, 2011). It is considered a structured pathway to achieving education and training goals.

Informal learning is never organised, has no structured learning outcomes and is not intentional in the learner's eyes (Werquin, 2010). It is also referred to as experiential or incidental/random learning and does not usually lead to certification, though it may be validated and certified (Cedefpop, 2023).

Non-formal learning sometimes referred to as semi-structured learning, is also intentional from the learner's perspective but includes activities that are not specifically designated for learning. It may also be validated and lead to certification (Cedefpop, 2023).

According to Hodson (1998), the objectives of science education in schools are determined by different stakeholders such as parents, scientists, policy-makers, and others. These objectives can range from cultivating the next generation of scientists to meeting the economic and social demands of the country (Malta Council for Science and Technology (MCST),[1] 2000), as well as promoting responsible citizenship.

The term ‘scientific literacy’ was coined by Paul DeHart Hurd back in 1958 and has become a global and well-recognised educational slogan (Laugksch, 2000). Despite being undervalued in the field of science communication, scientific literacy is considered the foundation of science education (Holbrook & Rannikmae, 2009; MCST, 2000). The underlying basis for the prevalent undervaluation of science literacy among science communicators is an area of interest that warrants deeper scrutiny, as discussed in section 1.3.2.

According to the 2022 PISA report from the Organisation for Economic Co-operation and Development (OECD), scientific literacy is defined as the ability to engage with science-related issues and ideas as reflective citizens. It encompasses skills such as explaining phenomena, evaluating scientific inquiries, and interpreting data. This definition highlights the importance of applying scientific knowledge in real-world contexts for informed decision-making. The concept of scientific literacy has been subject to diverse interpretations (Hodson, 1998). This variability is primarily attributed to contextual factors, the field of study, and the learner's objectives, who may come from different backgrounds and age groups. One of the aims of science education is for citizens to be able to make informed decisions revolving around scientific issues (Baram-Tsabari & Osborne, 2015), which is why scientific literacy in science education focuses more on content knowledge.

Different definitions of science literacy often reflect the priorities and contexts of the entities or academics proposing them, leading to complexities in understanding its overall meaning. For instance, the OECD (2023a) defines science literacy primarily within formal education, emphasising student engagement and knowledge acquisition. In contrast, definitions arising from citizen science projects focus on informal contexts, highlighting public participation and applying scientific understanding in

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[1] “The entity has now transitioned to XjenzaMalta, a governmental agency tasked with managing all activities related to research and innovation. This includes the development and execution of policies, as well as national, EU, and international financial programs pertinent to these sectors and initiatives concerning space. The agency operates from the Malta Interactive Centre for Science (Esplora) and will also assume the roles and responsibilities previously held by the Maltese Council of Science and Technology.”

everyday life. To resolve these complexities, it is essential to recognise that science literacy can encompass a spectrum of relevant competencies across various settings, integrating formal educational goals and the practical engagement of citizens in scientific discourse and decision-making. This broader perspective allows for a more inclusive understanding of science literacy that values diverse contexts and applications.

1.3.2 Deficient public or publics? From PUS to PEST

According to Bowater & Yeoman (2013), science communication has gone through three overlapping phases in the UK: science literacy (1985–1989), public understanding of science (PUS) (around the early 90s) and public engagement with science and technology (PEST) (early 2000s). There are various definitions of all the terms mentioned, and the context tends to be country specific (Bowater & Yeoman, 2013). Gascoigne and Metcalfe's (2020) global analysis of science communication in 39 countries highlights the timelines of the areas of activity that were significant in the respective country. This sheds light on what countries thought was important at specific points. These authors reflect on fourteen indicators spread over three conceptions of science communication:

- Indicators relating to science communication as *an area of practice*. These indicators include the creation of associations of science writers, journalists, and communicators, as well as the date of inception of interactive science centres.
- Indicators relating to *media as a subfield of science communication*. These indicators include the dates of the first significant radio/television programmes on science.
- Indicators relating to science communication as an *academic field*. These include dates of when university courses were created to train science communicators.

Having a scientifically literate 'public' meant that citizens could understand and keep up with the scientific and technological developments (such as the space race) (Ventura, 1996), or so governments thought. There are a multitude of variations of what scientific literacy means (as seen in Broks, 2006 and Millar, 2008), all of which depend on the context and specific field (i.e., education or communication).

Early definitions of scientific literacy include Shen's definition (1975), which explains this term in three forms: practical, cultural, and civic. Science is practical as it can be used to assist and improve living standards; cultural as science is seen as a great human achievement; and civic as citizens are able to participate in the democratic process of an increasingly scientific and technological society (National Academies of Sciences Engineering and Medicine, 2016). For Miller (1983), being scientifically literate was based on four components: knowledge of basic scientific facts, an understanding of scientific methods, an appreciation of science and technology, and a rejection of superstitious beliefs (Gregory & Miller, 1998). In 1991, John Durant argued that scientific literacy is inclusive of three major aspects:

cultural, practical, and political (Broks, 2006). Later, Durant refined these definitions to science content, science procedure and practice (Broks, 2006).

Governments realised, through surveys, that while a science literate population would be able to make informed decisions about policy issues around scientific topics, 'the public' was not aware of basic scientific facts (National Academies of Sciences Engineering and Medicine, 2016). The 'general public' was seen to have a deficit of scientific knowledge leading to what is known as the linear form of communication — the deficit model (Trench, 2008). In the UK, the report, more commonly known as the Bodmer report (after Sir Walter Bodmer, who chaired the Royal Society), is regarded as the key publication describing the 'deficit' model of science communication leading to the PUS movement (Bowater & Yeoman, 2013). According to Bowater and Yeoman (2013), while this report has been heavily criticised in the field of science communication, it did call for an improvement in formal education.

Scientific literacy was considered to focus on and tackle the knowledge gap; however, PUS's aim was to tackle a 'deficit' in attitude (Bowater & Yeoman, 2013). The PUS phase was criticised as science was seen as an area where the expertise lies completely with the scientists (Bowater & Yeoman, 2013; Gregory & Miller, 1998). Problematically, scientists were seen as having the authority to discuss science as they were the 'experts', while society was viewed as lacking knowledge and consequently, 'the public' needed to understand science (Broks, 2006). Another cause for concern was the assumption that if society knew more about science and technology it would inevitably make citizens more accepting of new technologies and interested in the subject (Bowater & Yeoman, 2013). Bodmer aimed to promote communication between scientists and 'the public' to boost support for science. However, PUS was sometimes viewed as an effort to legitimise the promotion of new scientific advances and technology rather than just popularising science (Broks, 2006).

The PUS movement can be summarised as adopting two polarised positions: it could be seen as a public relations exercise or to justify the value of spreading scientific knowledge widely (Broks, 2006). During the catastrophic Chernobyl nuclear accident in 1986, there was a clear instance where the expertise of citizens was disregarded simply because they were not scientists. Farmers who could assist in determining the right course of action following the accident were not consulted, leaving them feeling unwanted and unappreciated (Bowater & Yeoman, 2013). The government insisted that 'the public' must understand science to be able to contribute to the workforce (Gregory & Miller, 1998). In the same year, a similar situation arose during the bovine spongiform encephalopathy (BSE) crisis, also known as 'the mad cow disease' (1986). The BSE crisis was heavily reported in the media, and citizens were left feeling that scientists, governments and the media could not be trusted in making decisions about their personal health, as they all seemed to lack the understanding of how this disease was being transmitted (Gregory & Miller, 1998). This was the perfect example of a top-down approach where decisions were taken irrespective of what society thinks (Macnaghten, 2020). According to Fuller

(2002), the discipline of science is often granted the authority of an all-knowing entity because of its tendency to promote truthful and reliable information.

The focus then shifted from the deficit, linear, one-way approach (PUS) to a dialogic one (Russell, 2021; Schäfer, 2009; Trench, 2008). The third and current phase following the PUS era is called PEST, with less emphasis on facts and focus shifting to two-way engagement models of communication (Bowater & Yeoman, 2013). Before the PEST movement, dialogues or two-way communication still took place (Bowater & Yeoman, 2013). An example of two-way communication taking place during PUS dominance is that of a citizen jury in 1994 at a conference for plant biotechnology, where 16 citizens set the agenda and were expert witnesses and judges (Bowater & Yeoman, 2013).

It is worth noting that the concept of a 'deficient public' has been explored until now. The term 'public' assumes that everyone has the same interests and interacts in the same manner and for the same reasons. The term 'publics,' on the other hand, acknowledges the various subgroups within society, all with different reasons for engagement (Einsiedel, 2008). Publics have been distinguished by social categories, such as citizens, consumers, or users versus non-users (Einsiedel, 2008).

Dialogue events include, but are not limited to, café scientifiques, citizen juries, people panels and opinion polls (Bowater & Yeoman, 2013). Arts and artistic media have provided spaces for scientists, artists, and other publics to engage in dialogue (Einsiedel, 2008). In theory, these dialogic events are favoured over the deficit approach. However, Sarah Davies, who evaluated dialogue events at the Dana centre in London, found out that these types of events included both elements of deficit and dialogue (Bowater & Yeoman, 2013). Other shortcomings of the PEST approach include involving a limited number of people who are not representative of the entire population, as well as participants who cannot assist with shaping the agenda (Bowater & Yeoman, 2013). Other limitations include the inability of the event organisers to feed into policy, participant expectations that need to be managed, the difficulty in translating dialogic events to large audiences (Bowater & Yeoman, 2013), as well as attracting citizens who are already interested in science rather than the disengaged (Jensen et al., 2021).

As Bowater & Yeoman (2013) note, deficit approaches were still taking place while PEST approaches were favoured in the early 2000 (Trench, 2008). Such a restricted view that emphasises the dichotomy between the two approaches led to a narrow perspective of understanding this narrative (Bowater & Yeoman, 2013). Dialogue and participation still took place even during the early days of the PUS approach and there continue to be plenty of activities that still use deficit model approaches (Irwin, 2014). According to Trench (2008), the shift from PUS to PEST is still an ongoing process, and it is possible for both approaches to coexist. Nevertheless, the PEST approach does provide a viable means for social scientists to engage multiple publics in addressing complex issues such as those related to nanotechnology, as suggested by Irwin (2014). Science communication does not only involve the simplification of research into a language that an audience with a different background than science can understand, but it also takes on a variety of different forms (Davies & Horst, 2016). Understanding citizens' attitudes and perceptions towards science and technology is crucial for developing effective strategies to engage them with science.

International surveys give indications on how citizens' attitudes and perceptions about science and technology can shed light on how those working on engaging citizens with science can better understand publics to develop appropriate educational materials, outreach programmes and strategies (American Academy of Arts & Sciences, 2018). Other reasons to justify collecting data on the perceptions and attitudes of citizens include gaining the public's trust and support of its citizens (National Science Board, 2020; Ho et al., 2015). Rerimassie et al. (2015) state that throughout history, the development of science and technology is affected by how citizens perceive it.

Some of these surveys aim to understand citizens' perceptions and attitudes about science by assessing their scientific knowledge (as cited in Pardo & Calvo, 2002) to test their level of scientific literacy (Gastrow & Ishmael-Perkins, 2021; Bowater & Yeoman, 2013). While science literacy influences citizens' attitudes towards science, other factors include the social, political and economic variables (Gastrow & Ishmael-Perkins, 2021). Comparing the results from these surveys will be limited as the survey questions are not the same. Furthermore, the differing cultures and beliefs of the specific country also limit comparison (Ho et al., 2015; Pardo & Calvo, 2002).

In the early 1980s, Miller et al., divided citizens into three groups: the 'attentive, interested and the rest' of the public (Pardo & Calvo, 2002). The first survey that was commissioned by the Department of Business, Innovation, and Skills (BIS) in the UK in 2011 identified six audience clusters: the concerned, the indifferent, late adopters, confident engagers, distrustful engagers, and disengaged sceptics (Department of BIS, 2011). While both studies try to understand society by making a distinction between different groups of citizens, it would be better to try to capture these groups by thinking of the following groups as ranges rather than fixed subsets in society.

The *concerned* are those that tend to be more religious or spiritual, although cannot be called anti-science, and are concerned with the scientists' intentions (Department of BIS, 2011). Other traits from this group highlight the notion that this group is not convinced about the benefits science can provide to the economy. Furthermore, the concerned appear to have positive attitudes towards government and their efforts to consult with the public about science (Department of BIS, 2011).

The *indifferent* are described as older citizens (usually over 75 and retired) and tend to be less informed, interested or involved (Department of BIS, 2011). They do not hold positive or negative opinions about science and usually do not involve themselves in public consultation as they think that science is not for them.

Late adopters on the other hand are quite young and had a bad experience at school but are now more enthusiastic about science and are more interested in decision-making processes related to the environment and ethical concerns (Department of BIS, 2011).

The *confident* engagers are usually well educated and feel confident about engaging in science and tend to trust scientists and their relationships with the government but are less trusting of how the media reports science to its citizens (Department of BIS, 2011). While they are interested in the decision making process, they are also willing for experts to be involved.

The *distrustful engagers* are well educated and tend to come from science or engineering. While they are very interested in science believe in its potential to aid society, and are relatively well informed, they tend to be less trusting of those working in science and less confident about the government's role in regulating these workers. While this group tends to be sceptical about the consultation process, they believe that society should play a role and be involved in decision making on scientific issues (Department of BIS, 2011).

The *disengaged sceptics* are usually less well educated than the other clusters mentioned above and tend to feel less informed about science. This is usually because of their school experience, and this cluster tends to find science difficult and overwhelming, resulting in little science. This group is not particularly willing to get involved in decision making related to science and technology, but still want the Government and scientists to take note of citizen's opinions on science issues (Department of BIS, 2011).

To better comprehend and classify citizens into distinct publics, it becomes imperative to comprehend the communication strategies and mediums employed by these publics while interacting with the stakeholders in the field of science and technology. Such an understanding can potentially aid in designing effective communication strategies to bridge the gaps between different publics and stakeholders, thereby engaging citizens with PES and informed decision-making. Having a restricted view and emphasising the narrative of PUS or PEST tends to ignore other formats and stakeholders, such as the role of mass media in public science engagement (Davies & Horst, 2016).

The relationship between scientists and citizens is constantly evolving, thanks to the internet and its various platforms for sharing information like videos, blogs, social networks, and mobile devices (Peters et al., 2014). While the internet has made it easier for citizens to engage with science and provide feedback, increased participation does not necessarily lead to better public dialogue (Peters et al., 2014). The internet has also blurred the lines between different spheres of communication, such as the public and professional spheres (Lewenstein, 1995; Bucchi, 1998), and has highlighted the role of popularisation in science (Gregory & Miller, 1998) due to the increased prominence of overlaps. In the past, journalists acted as intermediaries and gatekeepers for scientific information, but the internet has created opportunities for scientists to communicate directly with citizens (Peters et al., 2014). However, even with direct communication, information can still be misunderstood if it is not communicated clearly.

While facilitating access to knowledge (Trench, 2008), the internet is used to misappropriate and enable the disinformation of science (Albrecht et al., 2022). False content that is represented as fact, whether intentionally or not is defined as misinformation, while disinformation obscures the truth (Albrecht et al., 2022). A clear example of this could be observed during the COVID-19 pandemic, with social media being used to disseminate good and bad information. So much so that the World Health Organisation (WHO) declared that an infodemic is receiving too much information - be it good or bad - making it difficult for citizens to make decisions about their health (WHO, 2022). The COVID-19 pandemic has prompted scientists to communicate their work to citizens, which was not encouraged before (Albrecht et al., 2022).

Schäfer (2009) explores the concept of 'medialisation', referring to changes in how mass media covers science. The respective literature covers three dimensions: extensiveness, pluralisation, and controversy.

- Extensiveness states that science's representation in the media is on the rise,
- Pluralisation refers to the diversity of actors and content of the media coverage on science,
- Controversy refers to the rise of media science coverage as being controversial (Schäfer, 2009).

Woolley and Joseff (2020) explore dealing with false information through media literacy while; some see it as giving citizens the necessary skills to evaluate disinformation, others contest that this places too much emphasis on the individual and absolves policy-makers, civil society experts and social media platforms from taking more responsibility. The core principles document defines media literacy education as encouraging active inquiry as well as critical thinking regarding messages that are received and created (Bulger & Davison, 2018; Alliance for a Media Literature (AMLA), 2007). Although media literacy is crucial, it is important to acknowledge that the media landscape is intricate, and there are other factors that influence how messages are formulated and perceived by citizens (Bulger & Davison, 2018).

Citizens consume media content from different platforms, be it digital, printed, visual or through audio, that can influence civic participation in science and technology. The type of content plays a role in determining the type of citizen participation encouraged. The history of the country such as South Africa with its colonial and apartheid ideologies also has an impact of how content is produced by the media (Plessis, 2015). Surveys indicating how citizens consume science content across different media indicate what PES institutions need to do to encourage civic participation.

In Australia, the majority of respondents to the beliefs and attitudes towards science survey stated that they use television (22.3%), online news websites (32.7%) and newspapers (30.6%) to inform themselves about science (Australian National Centre for the Public Awareness of Science (CPAS), 2018). An overwhelming majority of the respondents state that they do not use events or activities (99.2%) to inform themselves about science (CPAS, 2018). Social media platforms such as Facebook (9.0%) and Twitter (1.3%) are also quite unpopular platforms for citizens to acquire information about science (CPAS, 2018).

Americans use the internet to inform themselves about science and technology, citing that it is their primary source of information (57%) (National Science Board, 2020). Singaporeans' preferred source for scientific information was the internet, surpassing print media and television (Ho et al., 2015). As in other countries, the internet is increasingly getting more popular as an outlet for information.
The European member states also prefer television (63%) as a preferred means to obtain information, followed by online social networks and blogs (29%) and online and printed newspapers (24%) (EC, 2021). Such a global information overload presents further challenges to designating truth and trust (Gastrow & Ishmael-Perkins, 2021).

The media has always been a way of facilitating scientific content to society, even though it is sometimes reported in a distorted manner. Understanding citizens' preferred media can help science communicators, scientists and anyone wanting to disseminate research findings to reach a wider audience. This perpetuates the deficit model if it simply stops at just giving out information. Nevertheless, various social media platforms (such as Facebook, Twitter, Instagram) allow citizen interactions by offering a platform where citizens can comment and discuss.

1.4 Democratisation of science and technology – Science for all?

1.4.1 Diversity in STEM/STEAM through science education and communication

The slogan 'Science for all' has long been prevalent in school science, with variations of the same phrase being found in different countries globally (Mutegi, 2011; Fensham, 2004). It is a phrase that encompasses various aspects, such as political, social, and cultural factors. Although it appears to be straightforward, this mantra has multiple interpretations, including the accessibility of science to all and the knowledge and processes that all students should acquire (Mutegi, 2011). However, this leaves to question how the process of 'acquiring' science can be achieved, and whether teachers should attain science for all. Once these are addressed, educators turn to the critical discourse that should accompany reform efforts (Mutegi, 2011).

The idea of science curricula being designed to cater to social changes is not a novel concept. Despite the professed aim of inclusivity, science education reform still heavily emphasises Western cultural norms and overlooks the contributions made by earlier civilisations such as Egyptian, Greek, and Arabic. As a result, students tend to view Western science with reverence, while other cultural perspectives on science are excluded from their education (Mutegi, 2011). Furthermore, although science education is meant to reach out to 'all', education systems tend to favour children of wealthy and well-educated parents rather than those coming from disadvantaged backgrounds (Fensham, 2004). In his groundbreaking work "Pedagogy of the Oppressed", Paolo Freire explains how education is meant to free people's minds and liberate them from the restrictions of social classes and structure (Freire, 2014). To address diversity and equity in the classroom, the sociocultural factors accounting for the systems of power in science, technology, engineering and mathematics (STEM) education need to be acknowledged (Burgess, 2022).

Common aims between science practitioners, educators, teachers, and researchers include encouraging young people to take STEM courses and careers. Unfortunately, students' negative perceptions of science can impede their progress in science-related fields. Key factors contributing to this include students' self-perceived competence in STEM subjects (Regan & DeWitt, 2015), their experiences with science in school, and whether their envisioned future careers align with gender norms (Regan & DeWitt, 2015; Krapp & Prenzel, 2011). To address these challenges, science communication practitioners can leverage humanities and the arts, such as storytelling (Joubert et al., 2019), to train researchers to use creative approaches, including the arts, in STEM education. This approach is known as STEAM - Science, technology, engineering, arts, and mathematics - and is an effective way to engage students with STEM (Segarra et al., 2018). In a similar vein, an academic pilot study was conducted in Malta, which brought together a team of researchers, a non-governmental organisation (NGO), a group of participants, and a creative entity to create a theatre production aimed at challenging the stigmatisation and misinformation surrounding human immunodeficiency virus (HIV) (Gatt et al., 2021).

Public engagement with science (PES) needs to be mutually beneficial to all stakeholders involved with the purpose of informing, consulting and collaborating after having identified the aims and objectives for engagement, an audience, and an appropriate method to engage (National Coordinating Centre for Public Engagement (NCCPE), 2016). The RRI framework adds another dimension to engaging with publics: that of collaborating through a shared responsibility (Italian Presidency of the Council of the European Union, 2014). Citizen engagement occurs in a wider social, political, and economic context highlighting that past and present forms of science communication do not happen in isolation (Davies & Horst, 2016).

RRI advocates for more inclusion of citizens within the research process and citizen participation, known as citizen science - a concept that has been adapted by several disciplines. While various definitions of citizen science exist, the EC defines it as *"*Scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions” (EC, 2016, p.54)

Similarly, the US citizen science crowdsourcing act which was signed into law in 2017 defines citizen science more broadly. This definition sees society as being able to willingly address real-world problems through the scientific process of formulating research questions, conducting experiments, collecting and analysing data, interpreting results and making new discoveries (Holdren, 2015).

Citizen science is often associated with science education, outreach activities or various forms of PES (Roche et al., 2020). In 2015, the European Citizen Science Association Network (ECSA) released a publication detailing the ten principles of citizen science, which has been translated into over twenty-six languages (Hecker et al., 2018). Embracing the inclusive dimension of RRI, citizen science provides a platform for the intersection of science and society, engaging a broad spectrum of individuals in innovative processes beyond the minority (Hecker et al., 2018).

Criticism in relation to citizen science projects includes the participation of citizens that focuses on the needs and expectations of the scientific community rather than the citizens’ concerns (Davies & Horst, 2016). Another criticism of citizen science projects is that participants tend to be in possession of a tertiary level of education that lacks inclusivity and engagement in sectors of society (Haklay, 2018). Participation in citizen science projects needs to be spread more evenly across the population to engage less educated and privileged citizens (Hecker et al., 2018). Keislinger et al. (2018) assert that these programmes need to be evaluated based on three dimensions: scientific impact, participants’ learning and empowerment, and the impact for wider society. Continuous evaluations help with refining the design and delivery of the event or activity, which also assists with understanding the impact and future implications of the event (NCCPE, 2016). These criticisms are not limited to citizen science projects alone, as stereotypes and gender imbalances also persist within the scientific community.

Unfortunately, the notion of the white male with fuzzy hair in a lab coat scientist persists (Jarvis, 2018). Williams and Best’s study (1990) shows that other stereotypes associated with gender include how males were associated with aggression, dominance, autonomy, and achievement, while females were associated with nurture, relationships, and reverence (Dalyot et al., 2022; Sachdev, 2018). Despite progress being made in gender imbalance, women tend to be belittled or mansplained, which is quite prominent in fields where women are underrepresented (Dalyot et al., 2022). Mansplaining is when men try to explain something to women in a patronising way, irrespective of whether women know better than them or not (Conner et al., 2018).

Gender stereotypes are also quite dominant in the social sphere, where the representation in the media is such that scientists tend to be male (Dalyot et al., 2022). A UK study looked into gender representations in the national press and found that 84% were male, while the focus of women featured in stories (50%) was on their appearance, compared to 21% of men (Chimba & Kitzinger, 2010).

Understanding societal norms can shed light on why women and men tend to enrol in certain courses (Sachdev, 2018). In America, women were graduating more in the fields of psychology and biological sciences, with the lowest number of women graduating in computer sciences and engineering (National Centre for Science and Engineering Statistics, 2021). Women's personal and gender identities, as well as their professional beliefs need to be taken into consideration when understanding women's lack of participation in historically male-dominated fields, such as engineering (Piatek-Jimenez et al., 2018)

Globally, there is an underrepresentation of women in mathematics (Bonham & Stefan, 2017), with women publishing in lower-impact journals. However, women in engineering publish in higher impact factor journals, but are cited less than their male colleagues (Ghiasi et al., 2015). Women who are in typically male dominated fields such as mathematics would dissociate themselves from typical 'female' traits, such as being emotional that are usually not associated with a career in mathematics (Piatek-Jimenez et al., 2018). As Lewenstein (2019) points out, a gender imbalance exists in the field of science communication, with females mostly taking up science communication courses.

Incorporating diversity and inclusion in various activities is essential to ensure that a broader range of individuals in society can be engaged and benefit from them. However, addressing social inclusion is often tackled by identifying the 'barriers' to people's lack of participation or attendance (Dawson, 2014) in science activities at science centres, museums, and other venues. Some identified barriers are geographical distance, money, lack of interest in the topic, physical accessibility, and language (Dawson, 2014). The lack of interest in science or specific topics is a complex issue. Inclusive science communication practices can be achieved through understanding and exploring the attitudes and the imbalances of power (Dawson, 2014). Besides identifying what can be done and celebrating by rethinking and redesigning informal spaces to make them more accessible to a broader range of people, further research can focus on tackling country-specific scenarios (Fiske, 2012).

1.4.2 Bridging the gap between science education and communication

In this literature review, both the fields of education and communication have been explored with an overlap in terms, approaches, processes, aims and goals, but in most cases, terms tend to be defined differently according to the specific academic field (Lewenstein, 2015). Science education and science communication have distinct emphases, with the former aimed at educating and the latter at engaging and entertaining citizens with science (Baram-Tsabari & Osborne, 2015). For science communication, engagement is a priority, while for science education, the priority is to educate, with entertainment and engagement seen as a helpful addition (Baram-Tsabari & Osborne, 2015). Another prominent distinction between the two fields is how science is framed. While in science education weight is given to what science says and how scientists conduct science, science communication researchers tend to view these positions as one of the ways of presenting potentially relevant knowledge and making sense of the world

(Baram-Tsabari & Osborne, 2015). Science educators are concerned with educating the next generation of scientists; similarly, science communicators working in science museums or interactive centres who work with young children do so by engaging children to cultivate and sustain their interest in science (Baram-Tsabari & Osborne, 2015). While the method and aims of engaging young children with science is different, both have the overarching goal of encouraging young students towards furthering their scientific studies.

Both science education and science communication "were originally motivated by a commitment to democracy" (Lewenstein, 2015, p. 256); however, science education seems to have moved away from political aspects and focused on the individual, while the science communication field has maintained its political goals. In science education, Paolo Freire's 'banking conception of education' can be compared to the deficit model of learning in the science communication field - a concept also mentioned in Romberg and Stewards' report on mathematics education (1987). Freire's conception of education wanted to overturn the oppression of the masses towards a better democratic society based on Marxist ideals (Lewenstein, 2015). Furthermore, Freire's concept of the deficit model points towards the role social power plays in the relationship between publics, sciences, and learning (Lewenstein, 2015). Democracy can only be sustained if citizens are able to participate and make informed decisions (Baram-Tsabari & Osborne, 2015). This view is shared in the EC White Paper (EC, 1995, p. 10), which states that since democracy works with a majority decision on the major issues, the amount of background knowledge needs to be increased. Baram-Tsabari & Osborne (2015) further argue that science education needs to expand further on what aspects of scientific knowledge need to be tackled so that its students can make informed decisions. The authors claim that science communication maintains that what is important is not increasing content knowledge but enhancing ways of engaging citizens in dialogue (Baram-Tsabari & Osborne, 2015) or storytelling (Joubert et al., 2019).

The arguments in this section tease the issues and opportunities presented in both fields (see Table 1.3). Meaningful communication between science education and science communication will encourage shared ideas, trends, and methods to increase mutual benefits (Baram-Tsabari & Osborne, 2015).

Table 1.3:

Similarities and differences between science education and science communication

	Science Education	Science Communication
Priority	to educate and engage citizens — with entertainment seen as a helpful addition.	to engage with education and entertainment as a helpful addition.
Weight	given to what science says and how scientists conduct science.	given to alternative perspectives by citizens, stakeholders, scientists, and researchers in the production of scientific knowledge.
Moved	towards student-centred approach**.**	away from the deficit approach and motivated by participation.
Connects with	citizens and encourages them to come to informed decisions. youth towards science and technology using IBL and other creative approaches.	children, youth and citizens towards science and technology using humanities, arts, and other engaging approaches.

1.4.3 Public engagement with science networks and organisations

Networks and organisations create spaces for their members to interact on a social level (Valencia & Cázares, 2016), where relationships are built on trust and cooperation (Provan et al., 2007). They provide science practitioners and people working in PES with different tools to democratise science and technology and make it more accessible. Communication technologies facilitate and sustain these interactions (Lehoux et al., 2018). According to Bryson et al., (2006) an effective network aims to develop cross-sectoral collaborations involving various communities and entities. Internationally, public engagement with science networks (PENs) are organised on various levels: national, global, trans-national or European. Global networks include Public Communication with Science and Technology (PCST), or the international network for science shops, the Living Knowledge Network. National networks are those networks based in countries such as the former Association of Communicators in Education and Science (AKSON) based in Russia or the Science Communicators Association of New Zealand (SCANZ). Some examples of European networks include the European Science Engagement Association (EUSEA) and the European Network of Science Centres and Museums (Ecsite). Trans-national networks extend beyond the boundaries of national countries, such as the network for the popularisation of science and technology in Latin America and the Caribbean (Redpop). While only a few examples have been mentioned, all these networks try to connect various groups of people working in science communication or science education to engage citizens and other stakeholders with science. This is similar to what citizen science networks try to achieve (Göbel et al., 2016). The effectiveness of these networks depends on whether they meet their members' expectations and needs. Göbel et al. (2016), state that such networks can provide a space for learning, offer resources, and/or spaces for networking.

1.4.3.1 Networks, members, and PE

My study defines a *network* as a national, global, European, or transnational association or organisation with a paid or unpaid membership structure. The network shares the same vision and works towards achieving a set of aims.

Public engagement networks (PENs) for this study are associations or organisations of practitioners and/or those for scholars of science communication and public engagement with science, including frameworks such as RRI or networks that practise the sustainable development goals (SDGs).

PENs connect different stakeholders: members of the European Federation for Science Journalism (EFSJ) are mostly people working in journalism (EFSJ, n.d.), while Ecsite and Association of Science and Technology Centres (ASTC) connect science practitioners working in science museums and centres (ASTC, 2022, Ecsite, n.d.). The PCST network aims to advance the theory and practice of science communication, with members' backgrounds varying from research to practice (PCST, n.d.). The Centre for Public Engagement within the American Association for the Advancement of Science (AAAS) facilitates dialogue between scientists and citizens and assists scientists with communication resources (AAAS, 2022). These are just a few examples of PENs, but all such networks serve the same purpose of having members working in PES. Similarly, citizen science networks all have similar aims: to connect stakeholders and members to work together with the goal of encouraging active participation in citizen science (Göbel et al., 2016). Some examples of citizen science networks include the Citizen Science Association (CSA), the European Citizen Science Association (ECSA), the Australian Citizen Science Association (ACSA), and the Chinese Citizen Science Association (CCSN).

1.4.3.2 Network theory for effective, sustainable or successful PENs

According to Raab et al. (2015), the reasons behind a network's formation can serve as a gauge of its long-term viability and effectiveness. However, this alone does not guarantee success. Factors such as the network's level of maturity and the quality of services it provides are among the key indicators of its overall success. Other indicators of network effectiveness are the number of active network members and having transparent governance structures within the PEN (Göbel et al, 2016). Provan and Kenis (2008) state that networking effectiveness also relies on collaborations achieved through collaborative effort rather than individually, such as engaging with various stakeholders. While a network needs to be visible to attract new members, retaining those members relies on its governance, structure and management (Dalton et al., 2020). This means that public managers need to stay in close contact with their members (Provan & Lemaire, 2019). Evaluating the network at the community, network and organisational levels determines the network's success in reaching its goals (Provan & Milward, 2001).

1.4.4 Participation of citizens with science and technology

Citizens' participation in science and technology is crucial for empowering communities to respond to societal challenges, and science communication has evolved beyond the conventional modes of deficit and dialogue. Trench (2008) explores this third model of science communication, adapted from PUS to PEST to participation. This is an adapted model of Trench's participation, as shown in Figure 1.2. It emphasises the importance of scientists collaborating with citizens to shape research and policy. Motivations for scientists and researchers to engage citizens vary and come about based on intrinsic, extrinsic, formal, and informal incentives, as stated by Hoffman (see Table 1.4) (National Academy of Sciences, 2018).

Figure 1.2:

Adapted framework of the social conversation around science taken from (Bucchi & Trench, 2021)

	Public Understanding of Science (PUS) ↔	Public Engagement with Science and Technology (PEST)	
Base Model	**Dissemination**	**Dialogue**	**Participation**
Sci-comm applications	Deficit, Defence, Promotion, Popularisation, Outreach	Engagement, Consultation, Interactivity, Deliberation	Chat, Play, Co-creation, Film & fiction, Art-science
Aspects of science	Findings: finished knowledge	Issues: applications and implications of knowledge	Processes: interpreting and (re-) constructing knowledge
Public Uses	Information, awareness, learning	Questioning, opinion, discussion	Sharing, creating, enjoyment, critique
Social perspectives	Science literacy: Scientisim, technocracy	Science in society: Mode-2, post-normal, post-academic	Society in science: Civic science, citizen science
Orientation	⟵ Purposive, Hierarchical, Formal, Closed		Non-Purposive, Participatory, Informal, Open ⟶

[2]

[2] Scientism: - "the belief that science is the superior knowledge system and can provide answers to all the questions worth asking." (Trench, 2008, p. 130)

Table 1.4:

Hoffman's four combinations of motivations and incentives

	Formal	**Informal**
Motivation	Extrinsic – Tenure, promotion, annual reviews, journal publishing, and training as rewards system in academia	Extrinsic – Gaining greater visibility among citizens, which may improve a person's status within the university.
	Intrinsic – Developing new research strategies and seeking new audiences to increase stature and impact both inside and outside academia	Intrinsic – Providing a sense of meaning and purpose, considering PE as part of their mission

Public participation is often used interchangeably with public engagement (PE), public, community, or stakeholder involvement. The Rio Declaration of 1992 and the Aarhus Convention of 2001 encompass three fundamental pillars of public participation concerning environment protection and stakeholder involvement: access to information, public participation in decision-making, and access to justice (United Nations Economic Commission for Europe (UNECE), n.d.).

Einsiedel (2014) classifies participation in science and technology into three purposes that are not mutually exclusive: policymaking, public dialogue, and knowledge production. Table 1.5 is taken from the United States (US) regulatory process in categorising public participation in terms of who the stakeholders are and how participation is manifested (Einsiedel, 2014). Governments, societies, scientists, and the media have all been mentioned as communicating science and are potential stakeholders, but this is certainly not an exhaustive list and is explored further in this chapter.

The scientific community has not yet determined whether it is their role to communicate with their peers, government officials, or different publics (Gregory & Miller, 1998). Jasanoff (2003) does not question whether publics need to be involved in technical decisions but rather is concerned with promoting meaningful interactions among various publics, such as policy-makers and scientific experts.

As this section has explored, different levels of participation depend on the scope of the engagement (see Table 1.5). The purpose of who and why stakeholders communicate science, research, and technology varies from democratising access to science to affirming power structures, such as scientists who are seen as the only experts and policy-makers who decide on a vision or a strategy.

Table 1.5:

Participation in science and technology (Einsiedel, 2014).

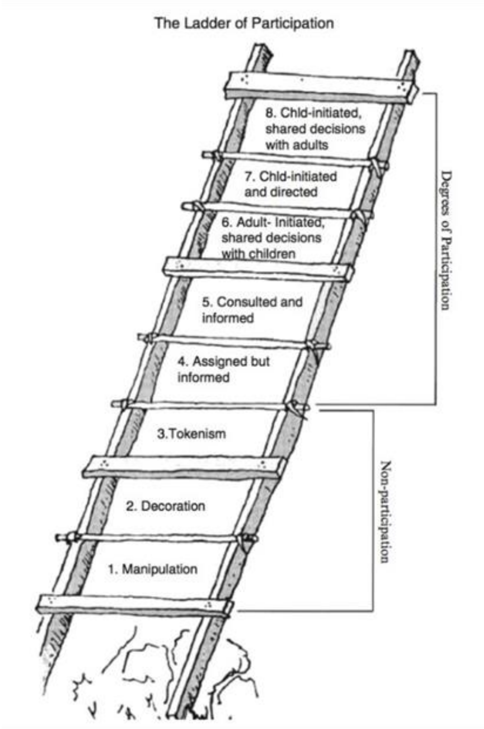
Purposes	Primary actors/sponsors	Examples of public participation
Policymaking	Government, research institutions, international organisations, stakeholder organisations, citizen panels	Consensus conferences, citizen juries, deliberative polls, negotiated rule-making, crowdsourcing
Dialogue	Government, research institutions, scientist/research networks, stakeholder organisations, public collectives	Science cafes, festivals, art/science exhibits, online discussion boards
Knowledge production	Scientists/research networks, community groups, citizens	Citizen science, traditional knowledge, crowdsourcing

Other models of participation considered in this study stem from Education, including Lundy's and Hart's models of child participation (Hart, 1992). These two models have gained significant attention as they reflect a paradigm shift towards recognising children as active agents in society rather than passive recipients in need of care and protection. While both models aim to promote children's involvement, their theoretical frameworks and practical implications differ.

Hart's Ladder of Participation is a well-known conceptual framework that outlines a hierarchical structure comprising eight distinct levels of participation, built on a broader version of Arnstein (1969)'s version of citizen participation. As depicted in Figure 1.3, this framework reflects varying degrees of adult control and child autonomy, with the higher rungs indicating greater levels of participation and influence (Hart, 1992). The lower levels, namely manipulation, decoration, and tokenism, are characterised by non-participatory practices often employed by adults in positions of power to demonstrate that children are somehow involved. Examples of manipulation include children carrying placards concerning their well-being or asked to create drawings of their ideal playground, but no feedback is given (Hart, 1992). The concept of decoration refers to instances where children are requested to present or wear certain items without a clear understanding of the purpose or context of the event. Tokenism, on the other hand, is characterised by a deceptive belief that children have a genuine say in decision-making processes while their voices are not considered. Despite being widespread and often well-intended, tokenism practices are manipulative and impede meaningful children's participation.

Figure 1.3:

Hart's model: Ladder of Participation



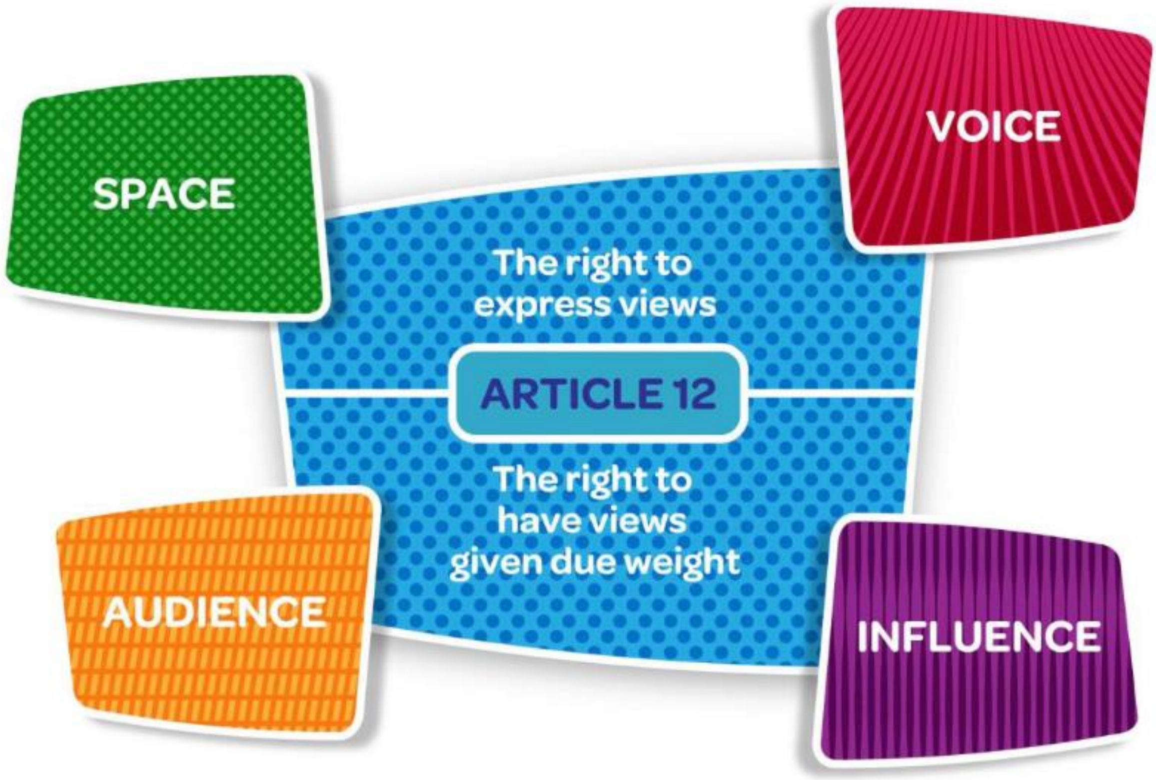
The fourth level involves children taking on specific roles within decision-making processes, while level five entails consultation with children on issues that affect them. However, the final decision-making authority remains with adults, and children's perspectives may not necessarily be acted upon. Level six represents a shift towards genuine forms of participation, where children are involved by adults during decision-making processes through their contributing their views and perspectives. The child-initiated and directed level involves adults supporting and facilitating children to take the lead in identifying issues and initiating discussions. In the final step, children are empowered to lead participation and have full control over decision-making processes, with adults serving as their advocates and allies for children's rights and voices. This underscores the importance of shared decision-making and collaboration and highlights the significance of empowering children to take ownership of issues and drive change in their communities (Hart,2022).

Both Lundy’s and Hart’s models prioritise valuing children's viewpoints and perspectives in decision-making processes. Hart's ladder distinguishes various levels of children's participation based on the balance between adult control and child autonomy, while Lundy's model highlights the four key elements: space, voice, audience, and influence (EC, 2007). At the centre of this model lies a landmark human rights treaty that sets out the civil, political, economic, social, and cultural rights of children set by the United Nations Convention on the Rights of the Child (UNRC). Article 12 states that children have the right to express their views freely in all matters that affect them and should be considered in accordance with the child's age and maturity. Additionally, children should be given the opportunity to be heard in any judicial or administrative proceedings that affect them (UNRC, 1989)

In Lundy's model (see Figure 1.4), space encompasses the physical, social, and emotional surroundings in which children can freely express their thoughts and engage in decision-making. These spaces should be secure, easy to access, and inviting to enable children's participation (EC, 2007). Children should be able to participate in significant activities such as group discussions, workshops, or community events where they can comfortably express their opinions without fearing criticism.

Figure 1.4:

Lundy's model of children's participation[3]



Voice points to children's ability to not be passive recipients of adult decisions but active agents with valid perspectives and insights, which goes beyond tokenistic gestures. Children are given opportunities for authentic dialogue and engagement by consulting on issues that affect them and inviting them to share their experiences and perspectives. By valuing and respecting children's voices, the Lundy model aims to empower them to make meaningful contributions in decisions that shape their lives (Lundy, 2007; EC, 2007).

[3] Lundy's model of children's participation as included in Ireland's National Strategy on Children and Young People's Participation in Decision-Making 2015-2020 (EC, 2007).

Audience refers to individuals or groups who listen to and consider children's views in decision-making processes. These are not only limited to adults in positions of authority, but can include peers, community members and other stakeholders. Lundy's model aims to foster a culture of openness, transparency, and accountability. By engaging diverse audiences this model ensures that children's perspectives are heard and considered across different spheres of society (Lundy 2007; EC, 2007).

Influence refers to the impact of children's participation in decision-making processes and outcomes. A shift in power dynamics ensures that children's voices carry weight and influence in decision-making processes. Adults are responsible for engaging children actively and considering their views, which ultimately aims to create a more inclusive and democratic society. This approach ensures that all voices are acknowledged and given due respect.

The frameworks established by Bucchi & Trench (2021), Einsiedel (2014), Hart (1992), and Lundy (2007) collectively foster enhanced participation in science and technology through a focus on communication, public engagement, and inclusivity. Bucchi & Trench (2021) highlight the importance of dialogue among diverse stakeholders, facilitating connections between scientists and the public. Complementing this, Einsiedel (2014) emphasises active public involvement in decision-making processes, ensuring that societal values are integrated into scientific practices. Furthermore, Hart (1992) and Lundy (2007) advocate for including children's rights and voices, underscoring the necessity of engaging young people in shaping scientific futures. Together, these models create a comprehensive approach that empowers all stakeholders, especially marginalised voices, to participate meaningfully, ultimately leading to more equitable and socially responsible advancements in science and technology.

1.5 The public sphere of science (PSS)

1.5.1 Dewey and Habermas

Building on the notion that scientific research can have significant moral, political, and social implications, Encabo, and Gil Martin (2007) emphasise the importance of the democratic inclusion of citizens in the field of science. Wain, (1994), highlights a paradox that writers such as Alasdair MacIntyre and Graham Haydon failed to tackle – that of preparing members to be an educated 'public'. Walter Lippman, a well-known editor and columnist, and John Dewey, a philosopher and educational reformer, were concerned with the relationship between education and communication (Feinstein, 2015). John Dewey wrote extensively about education, pedagogy, and the principles of democracy (Feinstein, 2015). Dewey believed that citizens should be active in society (Feinstein, 2015). It is worth noting that Lippman's view of democracy was somewhat elitist (Whipple, 2005), as he advocated for a more technocratic approach to governance. In this approach, decision-making would be entrusted to experts and intellectuals who are deemed better equipped to understand and address societal issues than the citizens in society. This approach differs from the traditional democratic model in which citizens are viewed as having the ultimate authority to make decisions through their elected representatives. The crux of the Lippman-Dewey debate is about citizens and expertise, where both ask what specialised knowledge is needed to participate in public debates (Feinstein, 2015).

As mentioned earlier, this is the same argument that prompted the PEST movement and continues to be debated. During the PUS movement, citizens were negatively defined as having something ‘missing’, often called non-scientists (Feinstein, 2015). The concept of the "public sphere" was initially introduced by Jurgen Habermas in 1962 (later translated to English in 1989) and is shaped by historical events and economic transformations, such as capitalism and global trade (Fultner, 2014). Contrary to Hegel’s view of public opinion as being subjective and separate from scientific inquiry (Hegel, 1991), Habermas recognises that public opinion can influence the production and dissemination of scientific knowledge through social processes, including the media, education, and public discourse (Habermas, 1992).

The concept of the public sphere, introduced by Habermas, builds on Dewey’s theory of education and society (Wain, 1994), and can serve as a valuable framework for understanding how science communication occurs in society. It is seen as a theory defining ideal speech while detecting communication that has been ‘distorted’, a theory of socialisation into acquiring communicative competence, and a theory of social evolution where society develops and changes over time (Wain, 1994).

Habermas defines the ‘public sphere’ as:

> A portion of the public sphere comes into being in every conversation in which private individuals assemble to form a public body. They then behave neither like business or professional people transacting private affairs, nor like members of a constitutional order subject to the legal constraints of a state bureaucracy. Citizens behave as a public body when they confer in an unrestricted fashion--that is, with the guarantee of freedom of assembly and association and the freedom to express and publish their opinions-about matters of general interest (Habermas et al., 1974, p. 49).

Habermas’s concept refers to a space where citizens can discuss and debate issues of public concern and are not hindered by other influences, such as the state and other powerful actors (Habermas, 2022). However, this study will also pay attention to frames that are typically not considered scientific, as well as narratives that citizens use to interpret research about science shaped by the media and institutions conducting PES events and activities. This study questioned whether citizens (publics) and their limits on individual scientific knowledge could come together, based on what has been received during formal science education, to facilitate the formation of a public sphere of science in PES events. Deliberative discourse can be used to understand how scientific knowledge is communicated to different stakeholders and the role of publics' participation in forming an opinion in a democratic society. Prior knowledge and prior mindset as described by Feinstein (2015, p. 151) are therefore crucial in citizens' interpretation of science. As Feinstein (2015) expressed, communication researchers view 'science news' which needs to be embedded within contemporary social concerns based on the specific publics. The term science news in this context refers to different media, online, print, and visual as well as any form of public participation in PES events and activities.

The rise of new media technologies, particularly social media platforms has altered the landscape of public discourse (Habermas, 2022). Criticisms of Habermas's public sphere theory suggest that this idealised notion of public discourse is subject to the influence of power dynamics, inequalities in access to information, and other structural constraints (Goode, 2005). Furthermore, it fails to account for excluding marginalised communities and publics from participating in public discourse (Fraser, 1990). Specifically, by applying the concept of the public sphere to the domain of science, insights into how scientific knowledge is produced, disseminated, and received by different actors in society can be understood. In this context, examining the landscape of science communication in Malta and exploring how the public sphere of science (PSS) operates is essential. Such analysis highlights the challenges and opportunities in PES and enhances the role of citizens in shaping scientific research and innovation policies.

1.5.2 Hegemony and Capital in Science

Science is often portrayed as the "hegemonic institution of truth" historically grounded in the struggles for meaning (Badino & Omodeo, 2021, p.1). As Badino and Omodeo (2021) note, the concept of hegemony, articulated by Antonio Gramsci, is particularly relevant for understanding the power dynamics in scientific knowledge production. Gramsci believed that the ruling class maintained its dominance through its institutions, the media, the education system, and other aspects of civil society. The dominance and control over the dominant discourse are done so through consent and cultural leadership established in the respective field or domain, which shapes the dominant ideology and is accepted as common sense.

Cooter (2021) recognises the economic dynamics that inform the relationship between science and society, and how they can shape the production and dissemination of scientific knowledge. While in the past, scientific knowledge was popularised to generate public interest, current scientific research is more expensive and requires significant venture capital to be undertaken. Moreover, the author suggests that while the scientific community claims that scientific knowledge should benefit society, the primary goal is to generate profit (Cooter, 2021). These dominant cultural norms within the scientific field impact PSS.

Power imbalances and societal barriers in science communication are prevalent. To tackle this problem, Archer and her colleagues utilised Bourdieu's theory on capital applied to science. Bourdieu defines capital as the resources and assets obtained and employed by individuals or groups to enhance their own power and influence within a social structure (Bourdieu, 1984). Bourdieu explored four forms of capital: economic, social, cultural, and symbolic (Bourdieu, 1986).

Economic capital is a form of capital that refers to tangible financial resources such as money, property, or investments. It plays a pivotal role in shaping one's social position by offering the means to purchase goods and services that have a significant impact on their socioeconomic status.

Social capital encompasses the various networks, relationships, and social connections that individuals cultivate. This can range from family ties, friendships, professional contacts, to affiliations with social organisations. By nourishing these connections, individuals can gain access to a wealth of opportunities, resources, and information, as well as establish a supportive network that can promote social mobility and influence.

Cultural capital includes the acquisition and possession of non-economic resources such as education, knowledge, skills, and cultural preferences. Educational credentials, intellectual abilities, aesthetic tastes and familiarity with cultural practices and norms are included in this form of capital which can give individuals social status and privilege.

Symbolic capital relates to the prestige, recognition or symbolic value attached to individuals or entities within a social field such as reputations, honour, symbolic distinctions, or cultural symbols that offer legitimacy or authority. This form of capital is frequently connected with social and cultural capital and can play a pivotal role in asserting power or authority in particular circumstances.

Archer and colleagues developed a quantitative measure for assessing individuals' science capital across various domains, including science-related experiences, knowledge, attitudes, and resources (Archer et al., 2015). This measure provides a valuable tool for researchers and educators interested in understanding and addressing inequalities in science education. While Archer et al.'s (2015), adaptation to science capital as a distinct form of capital has generated valuable insights, there are several key issues and limitations associated with this adapted concept. The framework developed focused on individual characteristics, such as knowledge, attitudes, and experiences, and neglected to consider or overlooked structural inequalities and systemic barriers (Jensen & Wright, 2015) in PES. Another critique of science capital is that students and citizens are seen as having a lack of necessary capital to engage in science, perpetuating the deficit model approach. Furthermore, Archer's concept of science capital does not tackle the mechanisms through which the dimensions of capital influence PES participation. An inadequate attention to power dynamics within the scientific community and their influence on science engagement is also lacking (Jensen & Wright, 2015).

The capital of science in this study referred to the various forms of resources and assets available to citizens and publics, within the public sphere and the scientific community. This study focused on

Bourdieu's four forms of capital (economic, cultural, social, and symbolic) (and applied them to science and PSS. This theoretical lens provided this study with an understanding of how power, hierarchy and social structure shape the scientific field, inherently influencing interactions within PES.

To this end, the science capital concept developed by Archer will be further explored based on the critiques already outlined to counteract the lack of intersectionality and power dynamics that are already highlighted in Bourdieu's concept of capital. The rationale for comparing and deliberating on the concepts of science capital and the capital of science stems from Bourdieu's initial creation of the concept of capital to empower citizens and publics. Archer and her colleagues subsequently expanded upon this idea, aiming to enhance citizen empowerment through the notion of 'science capital.' However, Jensen points out several oversights, the most significant of which is the failure to recognise the role that various entities play in the democratisation of science within the PSS.

The following equation developed by Bourdieu was applied to analyse the Maltese islands' PSS.

[(Habitus) (capital)] + scientific field = practice[4]

Habitus – This is a product of socialisation that operates at an individual level. The way society is organised in terms of social classes becomes ingrained in our minds, often not realising its impact.

Capital – Resources that one can possess **-** Can be economic, social, cultural, and symbolic.

Field – The specific field of study in this case Science.

Practice – The actions and behaviours of relevant stakeholders within PSS.

1.6 Stakeholder Theory

The term 'stakeholder' tends to have different definitions depending on the context (Bonnafous-Boucher & Rendtor, 2016). For Freeman (1984, p.46) it is defined as "any group or individual who can affect or is affected by the achievement of the organisation's objectives." Furthermore, Roeder (2013), states that a stakeholder can be an individual, group, or organisation. While individuals do not require communication with others, groups or organisations tend to have a person or a small group within the organisation to represent their members (Roeder, 2013).

According to the European Observatory of working life (EurWork, 2019) and for the purpose of this study,

> *"A stakeholder is an individual, group of persons or organisation that can affect or is affected by the decisions of another organisation. This definition also includes interest groups related to the organisation."*

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[4] Adapted version of Bourdieu's capital

Stakeholder theory is an amalgamation of broad narratives that is subject to multiple interpretations and applications be they corporate social responsibility (CSR), strategic management, corporate governance or business ethics (Miles, 2017). The foundation of stakeholder theory explores two main questions: the purpose of the organisation and the responsibilities organisations owe to their stakeholders (Freeman et al., 2004; Freeman, 1984). Such a broad definition is necessary so as not to exclude any vital stakeholder (Mitchell et al., 1997). The authors propose that groups of stakeholders are identified by one or more of the following attributions: "the stakeholder's *power* to influence the firm, the *legitimacy* of the stakeholder's relationship with the firm and the *urgency* of the stakeholder's claim on the firm" (Mitchell et al., 1997, p. 854). This typology is based on the notion of who the managers should pay attention to. For Malta's context, this can be applied to how crucial stakeholders conducting PES in the Maltese Islands are identified.

This will guide how PES stakeholders are identified for this study. Stakeholders can be identified as primary that is, having direct control over resources of the organisation *(*Marcon Nora et al., 2022*;* Barnett et al., 2015), or secondary, and hence would need to find other means to trigger organisational change (King, 2008). The digital age seems to have blurred the lines between the primary and secondary stakeholders (Mitchell et al., 1997). Due to the information age, secondary stakeholders hold greater power in affecting change and put pressure on primary stakeholders, such as politicians, to think about sustainable options (Shubham et al., 2018).

1.6.1 Stakeholder engagement and the five-step approach

Freeman and his colleagues (2017) offer an insightful framework for stakeholder engagement that encompasses stakeholder relations, effective communication, and learning with stakeholders. Their integrative approach to stakeholder engagement offers a valuable perspective for academics and practitioners alike seeking to optimise stakeholder engagement strategies in diverse organisational contexts. Studying stakeholder engagement can enrich our understanding of co-creating and creating alliances with stakeholders (Freeman et al., 2017). Integrative stakeholder engagement is determined by the power of relationships and the interconnections among stakeholders.

CSR is a way of holding companies accountable regarding the ethical running of their company. CSR is defined as 'the responsibility of enterprises for their impact on society' (EC, n.d.). Companies can become socially responsible by integrating the environmental, social, ethical, consumer and human rights concerns in their strategies and following the law. Morris and Baddache (2012) consider stakeholder engagement as something that is basic for CSR. Managers of companies have the task of engaging the appropriate stakeholders, however, other stakeholders and social media have an impact on how companies are engaging and whom they should engage with (Morris & Baddache, 2012). It has been observed in certain instances that organisations adopt a communication approach that treats engagement as a form of outreach or public relations (PR) initiatives. As a result, stakeholders are often selected based on their level of vocalisation rather than their degree of relevance, which may result in ineffective engagement tactics.

Business for social responsibility (BSR, 2022) proposes a five step-approach (see Figure 1.5) to making stakeholder engagement meaningful for a company:

Figure 1.5:

An adapted diagram of the BSR's 5 step-approach

This approach to stakeholder engagement presents the steps needed and highlights the benefits of the process by defining preliminary steps needed for strategy building (Morris & Baddache, 2012). The first two steps involve the building of a knowledge base to understand the reasons for engaging stakeholders over others. The next two steps, preparation, and engagement, ensure that the engagement is a process of continued dialogue with the chosen stakeholders. The final step in the five-step approach is the action plan, ensures that it is designed to translate the insights, findings, and agreements.

As per Morris and Baddache's (2012) recommendations on stakeholder engagement, in line with BSR's five-step approach, it is crucial to comprehend the significance of stakeholder engagement for an organisation. The identified steps aim to transform the organisation's approach from considering stakeholder issues as external problems that require management to viewing them as topics that necessitate attention and constructive communication.

The initial step in the five-step approach entails establishing a visionary framework that sets the tone for future engagements, as per the following sub-steps.

1.1 Identification of the history of engagement
1.2 Identification of the level of ambition
1.3 Setting a vision for engagement
1.4 Determination of who has a stake
1.5 Identification of the mode of engagement

It is important to begin by reviewing past engagement efforts to guide future activities and reach the desired level of success. The next step considers stakeholders' priorities in the mapping process, as this will inform the level of engagement needed. The third step involves crafting a clear and compelling vision for engagement, while also identifying the stakeholders that have a vested interest. Finally, the fourth and fifth steps focus on determining the best mode of engagement and executing a plan to engage the identified stakeholders (Morris & Baddache, 2012).

Stakeholder mapping, the second step in the five-step approach (see Figure 1.5) includes four phases to determine a list of key stakeholders:

2.1 Identifying
2.2 Analysing
2.3 Mapping
2.4 Prioritising

It is important to first compile a comprehensive list of stakeholders, which may include groups, institutions, and individuals. Next, it is crucial to gain an understanding of each stakeholder's perspective and relevance. In the context of stakeholder engagement, it is imperative to consider various factors such as the potential contribution of stakeholders, the legitimacy of their claim for engagement, their willingness to participate, and their influence to effect change in tandem with other stakeholders. In addition, identifying the key stakeholders who should be involved in the engagement process is crucial, as overlooking any relevant parties could potentially derail the process. Figure 1.6 highlights the expertise, willingness, and value that stakeholders to affect change. This can be accomplished by visualising their relationships through a mapping process (see Figures 1.6 and 1.7).

Mapping involves comparing stakeholders based on the same criteria as shown in Figure 1.6, and then plotting them on a grid as depicted in Figure 1.7. The grid is divided into four quadrants with expertise represented on the Y-axis and willingness on the X-axis. Stakeholders are ranked based on circle size, with larger circles indicating greater importance. The use of arrows to show influence helps to illustrate relationships. Finally, the fourth step involves prioritising stakeholders and identifying key issues (Morris & Baddache (2012).

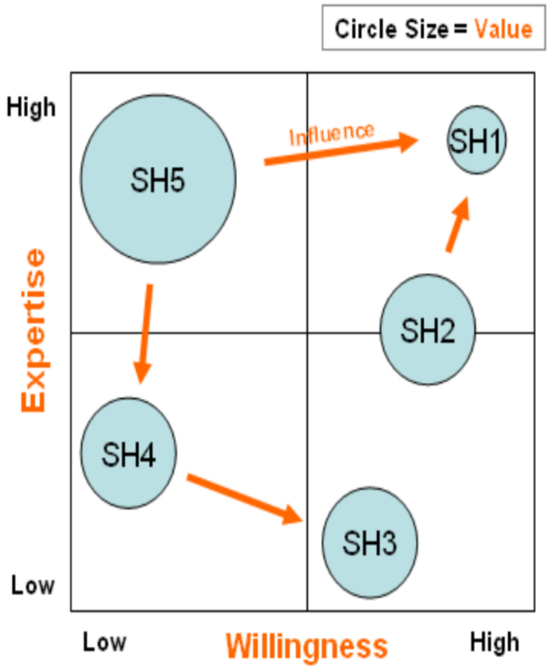
Figure 1.6:

An example of stakeholder mapping based on expertise, willingness, and value (Morris & Baddache, 2012, p. 11)

	Expertise		Willingness	Value	
Stakeholder	**Contribution**	**Legitimacy**	**Willingness to Engage**	**Influence**	**Necessity of Involvement**
SH1	**High:** Knowledge in X issue is of value to the company	**High:** Directly affected by our company's activity	**High:** Proactive group that is already engaging	**Low:** Relatively unknown group	**Low:** Not an outspoken stakeholder
SH2	**Medium**	**Medium**	**High**	**Medium**	**Medium**
SH3	**Low**	**Low**	**Medium**	**Low**	**Medium**
SH4	**Low**	**Medium**	**Low**	**Medium**	**Medium**
SH5	**High**	**Medium**	**Low**	**High**	**High**

Figure 1.7:

Visual sample mapping (Morris & Baddache, 2012, p. 11)



This approach recognises the significance of prioritising stakeholders, as it may not be feasible to consistently involve every stakeholder to the same extent (Morris & Baddache, 2012). To determine the stakeholders' level of involvement, it is crucial to consider the relevant issues pertaining to the engagement objectives and combine them with mapping and criteria to rank the stakeholders.

1.7 The social, cultural, and institutional dimensions of scientific practice

The sociology of science, also known as the sociology of scientific knowledge (SSK), examines the social, cultural, and institutional dimensions of scientific practice. It emerged as a response to the dominant positivist and functionalist approaches to the sociology of science (Nye, 2011). It became more established as a field of study during the 80's and 90's (Shapin, 1995). In the late 20th century and 21st century, Bruno Latour's actor-network theory (ANT) and feminist science studies initially aligned with SSK and emerged as various subfields and approaches (as cited in Nye, 2011). Karl Mannheim thought that scientific pursuit is affected by internal factors rather than external factors such as social or cultural influences (as cited in Nye, 2011). SSK's focus and concern was examining scientific knowledge production and validation rather than the social organisation of science and the norms governing scientific communities.

1.7.1 Actors, actants and Actor-network theory (ANT)

Although Latour's sociological approach initially aligned with SSK, the focus was different. SSK centred around the study of society in science, while Latour's idea was to study science in society, inspired by Foucault's philosophy. This philosophy highlights how scientific knowledge and technical expertise can strengthen the dominant social interests and the established political order (Nye, 2011). Latour's agenda was not solely aimed at questioning the alliance between science and the state, but it also challenged the legitimacy of the state itself.

Actor-network theory is a structuralist and constructivist approach in which there are both human and non-human actors (Cresswell et al., 2010; Gao, 2005). Actors are defined according to the role they play, their activity and the effect they produce in their respective network (Marcon Nora et al., 2022).

ANT incorporates mobility and flexibility in understanding the links between human and non-human actors, also called actants, that are believed to be in non-hierarchical networks (Marcon Nora et al., 2022; Sayes, 2014). This theory provides a useful beginning to understand the relationships between actors in organisational networks (Farrugia et al., 2022). ANT is a theoretical and methodological approach to social theory - a way of analytically looking at interactions of human actors and their effect on non-human actors and vice versa (Sayes, 2014). This theory proposes a systematic method to record how different actors negotiate and shape their environment (Latour, 1999).

According to Latour (1999), society is entangled in a web of complex issues, including the understanding of the world, psychology, politics, and theology. Latour seeks to comprehend the world in its natural state, how individuals perceive their surroundings, how political systems maintain order without infringing on individual liberties, and how theology distinguishes and links these various domains of reality. The focus is on the dynamic links between society and individuals. Latour, (1999) points out that while there is the word theory in ANT, it is not a theory of the social or a description of the pressure on actors imposed by society. It is, however, a method to understand actors without researchers imposing definitions, the sociology ontology of those trying to understand actors (Latour, 1999). Due to this, ANT researchers are not exactly ‘studying’ other social actors.

Within the PUS and PEST contexts, individuals are seen as deficient in scientific knowledge (PUS) or seen as possessing lay knowledge that can inform public policy (Bucchi & Neresini, 2007). Materials, technologies and objects are all part of the landscape and included as actors in their own right (Marres & Lezaun, 2011). These objects serve a role and are not simply a medium to share issues to publics (Michael, 2017). Publics are therefore understood in their entirety with the role of non-human actors such as technologies and devices that play and shape the politics of the issues (Michael, 2017).

For this study, stakeholder theory, engagement and mapping are used to identify and prioritise stakeholders, and ANT is used to include and explain the role and the politics that non-human actors, such as social media, play in understanding how publics engage with science.

1.8 The local context

Similar to what happened internationally, various indicators of practice such as science festivals, science centres and museums have shaped the local science communication landscape in Malta. This final section presents an overview of the formal, informal, and non-formal landmarks contributing to the current science communication scene.

1.8.1 Formal Science Education in the Maltese Islands

The history of modern science teaching in Malta at different levels dates back to the late 1950s and early 1960s (Ventura, 1996). At tertiary level it is reported that the Jesuits had founded a college and that there was a chair of mathematics in 1655 (Fiorini & Grima, n.d.). Science subjects were added to the school curriculum, and by 1964, there had been significant changes and progress in the field of science education, establishing the need for science methodology for effective science teacher education (Ventura, 1996). This sudden interest and increase was a worldwide phenomenon as it coincided with the space race era (De Hart Hurd, 1958; Ventura, 1996). This propelled society to develop the science curriculum even further to cater for the ever-growing demands of society (Malta Council for Science and Technology (MCST), 2000). Being science literate became essential such that citizens are empowered to understand and make informed decisions (MCST, 2000).

As reported by the Science Centre[5], the entitlement of primary state school students for the scholastic year in 2019/2020 was to have a minimum of one lesson per week delivered by the science peripatetic team that visits different schools (Science Centre, 2019). According to the Ministry for Education, Sport, Youth, Research, and Innovation (MEYR) for 2019, the average science instruction time for Year 5 Maltese students was 51 hours per year. This falls below the international average of 75 hours, highlighting the need for increased emphasis and allocation of time to science education for primary school students in Malta. This is crucial if Malta's students aim to compete on a global platform in the field of science and technology. In secondary schools, students continue to study generic science until Year 8 (11/12 years old) and then choose whether they want to study sciences, Information and communication technology (ICT), or other subjects. The choice tends to fall in three main categories: sciences, languages or business (Gatt, 2000). As part of the 2012 National Curriculum Framework and in line with the framework for the education strategy for Malta, vocational subjects were introduced in 2016 during the students' last three years of secondary education (European Centre for the Development of Vocational Training (Cedefop), 2017). The vocational subjects agribusiness, engineering technology, health and social care, hospitality and information technology were introduced at Malta Qualifications Framework (MQF) level 3 (Cedefop, 2017). As with other subjects, students can sit for the Matriculation and Secondary Education Certificate (MATSEC) examinations and acquire a grade between 1-7, one

[5] The Science Centre is a Ministry for Education, Sport, Youth, Research & Innovation (MEYR) satellite hub, hosting a team of STEM Education Officers responsible for the administration and policy-making of national STEM subjects within compulsory education.

being the highest. A school teacher highlights that school dropout is linked with students' lack of motivation and interest in subjects at school, indicating that VET can hold the key to counteract students from leaving school early (Spiteri, 2017, par. 1). Since these VET subjects normally include placements in industry, students are able to envision a possible future career.

Vocational education was neglected for too long in Malta and received limited attention from policymakers, indicating that academic training deserves a higher status (Times of Malta, 2022. Huge investments both financially and in increasing human resources in the Malta College for Arts, Science and Technology (MCAST) are a good starting point, but nevertheless, the college still faces some challenges. Those teaching vocational education need to have industry experience, besides being academically qualified to equip the students with the necessary skills (Times of Malta, 2022). Only time will tell to confirm whether these vocational and education training (VET) subjects truly offer students an alternative to other traditional routes.

MEYR has also been monitoring student attitudes towards mathematics and science through various international studies. In the 2019 Trends in International Mathematics and Science Study (TIMSS) by the International Association for the Evaluation of Educational Achievement (IEA), nearly half (48%) of Maltese Year 5 students enjoy learning mathematics a lot, which is slightly higher than the international average (45%), while, 18% of Maltese students do not enjoy learning mathematics, which is lower than the international average (20%) (Ministry for Education, 2019). Those who tend to like the subject scored better than those who did not enjoy mathematics. This is also the trend in other countries (Ministry of Education, 2019). On the other hand, 58% of Maltese Year 5 students enjoy learning science a lot, which is higher than the international average (52%). However, the Maltese students who do not enjoy learning science very much (12%) is slightly higher than the international average (13%) (Ministry for Education, 2019). Malta's mean score is higher than the previous TIMSS 2011 survey, implying that there is an improvement in enjoyment for Year 5 Maltese students to learn science (Ministry for Education, 2019). The same trend linking enjoyment to attainment is also present for science with students who stated that they enjoyed science very much scoring higher in science (Ministry for Education, 2019). However, Maltese students' mean score indicating students' confidence in science, while equivalent to the international average, is still marginally lower than the previous TIMMS cycle in 2011 (Ministry for Education, 2019).

The Programme for International Student Assessment (PISA) is another international comparative survey targeting 15-year-old students to assess their reading, mathematical and scientific literacy knowledge and skills towards their compulsory schooling (MEYR, 2022). This was launched by the Organisation for Economic Co-operation and Development (OECD) in 1997, and the first was administered in 2000.

The average science score of Maltese students in PISA 2022 was 466, which shows an increase of 5 scale points from the PISA 2009 cycle (461). Moreover, the score was one scale point higher than the PISA 2015 cycle (465) and nine scale points higher than the PISA 2018 cycle (457). These findings suggest that there has been a noticeable improvement in the performance of Maltese students in science over the years, which is an encouraging trend for the educational system of Malta. The correlation between the aforementioned initiative and its impact on students' inclination towards STEM education and career prospects remains a matter of further investigation.

The 2018 study notes that 32.3% of Maltese students reported to work in a science related career around 30 years of age with 13.7% working as health professionals, 11.7% as science and engineering professionals, 5.9% as ICT professionals 1.1% work as science technicians and associate professionals (MEYR, 2018). Like most countries within the PISA report, only 9.0% of Maltese boys report willingness to work in health as opposed to 18.1% of girls (MEYR, 2018). Students’ expectations are reflected by the support available, and opportunities presented (MEYR, 2018).

Science education at the University of Malta (UM) has a chequered past. The tertiary educational college was founded by the Jesuits in 1592 (Fiorini & Grima, n.d., par.1). The Jesuit’s Collegium Melitense became a public university - now known as the University of Malta where several European scientists joined this newly founded university. At this time, the university was made up of three faculties (Theology, Jurisprudence and Medicine) with all of them having a Master of Arts degree in subjects that included science and mathematics. This remained until the end of the Order’s rule in 1798 when Napoleon abolished the University (Fiorini & Grima, n.d., par. 3). This did not remain for long as it was re-instituted by Sir Alexander Ball in 1800. The Maltese academic Napolean Tagliaferro was appointed rector and divided the Faculty of Literature and Science into two distinct faculties - arts and sciences. The faculties were further divided into Arts, Science, Engineering and Architecture (recently named Faculty for the Built Environment) during Edoardo Magro’s rectorship between 1903 and 1920 (Fiorini & Grima, n.d., par. 5). The Faculty of Science was briefly dissolved in the early 1980’s but has been up and running since 1987 (Think Magazine, 2015). The separation between sciences and arts highlights the lack of interdisciplinarity that is required in the workforce. To account for this separation, STEAM approaches try to connect the arts with the rest of the STEM subjects (Segarra et al., 2018). To this day, this separation exists, to the detriment of the students as it could expand their horizons in terms of expression and ways of thinking. The BSc (Hons) in Science for Education and Communication by the Faculty of Education at the UM provides students with the opportunity to arm themselves with a sound background in scientific knowledge while learning different ways and approaches (including arts and the humanities) to communicate with various audiences (University of Malta, n.d.).

In 2022, more than half the tertiary-level graduates were females (55.6%) (National Statistics Office, 2022). This is also reflected in the international trend with young girls outperforming boys, however, girls tend to choose pathways with less-paid professions such as science, mathematics or computing leaving a negative impact on their labour market prospects (MEYR, 2018).

1.8.2 Informal and non-formal science education in the Maltese Islands

The Eco-Schools program, established in 1994 by the Foundation for Environmental Education (FEE), aims to encourage schools to actively participate in environmental decision-making and action. EkoSkola forms part of the non-formal education for sustainable development in primary and secondary schools, which aims to democratise the decision-making process and set relevant targets for improving the school's environment (EkoSkola, 2024).

Informal science education in the Maltese Islands could be associated with Guido Lanfranco's rich legacy of educating citizens on Malta's flora and fauna through multiple exhibitions and books (Vella, 2021). Through NGOs, the popularisation of science in Malta seems to revolve mostly around environmental conservation both on land and in the sea (e.g. Birdlife, Friends of the Earth, Nature Trust, Greenhouse Malta, Sharklab and others) and astronomy (the Astronomical Society of Malta). The events range from outreach to dissemination of information to citizen science projects and participatory approaches.

Other engaging activities include activities by the NGO Malta Chamber of Scientists (MCS) under the STEAM initiative at Spazju Kreattiv that bring four different activities combining STEM subjects with arts: Malta Café Scientifique, CineXjenza, Kids Dig Science and Science in the City festival (MCS, 2023). This NGO offers a much-needed space for local citizens to freely discuss science and technology, encouraging participation in the local public sphere. Other organisations, such as the Malta Chamber of Engineers, hold regular events to promote their profession through the initiative 'Engineer your career' and provide a forum to exchange ideas (Chamber of Engineers, 2024).

Science in the City (SITC) is a science and arts festival as part of the European Researchers' Night (ERN) initiative, which receives funding from the European Commission, government agencies, and other sponsors (Jensen et al., 2021). This annual event aims to engage, empower, and enable young people to consider STEM careers (MCS, 2023). This festival is estimated to attract approximately 30,000 people annually and holds events in the streets and buildings of the capital city of Valletta. The activities range from interactive performances to art exhibitions and hands-on activities (Jensen et al., 2021). At the SITC festival, it was observed that most attendees held either undergraduate or post-graduate degrees. However, there was a noticeable lack of representation from individuals without formal educational qualifications in Ireland and the UK, with the situation being most pronounced in Malta (48%) (Jensen et al., 2021). Although ERN events are intended to be inclusive of all members of society, regardless of their educational background or social status, it is essential to address the issue of exclusion based on access to and progress in formal education (Jensen et al., 2021).

A Malta Café Scientifique event was held in 2020 to discuss issues that women face if they want to study STEM subjects at school or higher education, together with why it is difficult to retain women in STEM careers (Malta Café Scientifique, 2021). Other initiatives to encourage girls interested in ICT and the digital sectors included a workshop organised by Esplora in collaboration with ESkills Malta Foundation and a consulting agency for girls aged 12 to 14 where students could learn from professionals (Esplora Interactive Science Centre, 2024a). Despite the efforts of numerous NGOs and institutions to promote science and technology among women and girls, there has been a lack of coordination and follow-up among these organisations, resulting in stand-alone events. However, in 2023, Malta was named the world capital for women and girls in science and technology by the Royal Academy of Science International Trust (RASIT), prompting various entities to unite in their efforts to encourage and support female participation in STEM fields from primary school through higher education and beyond (UM, 2023). Despite receiving positive feedback on these initiatives, a minority of male secondary students and adult male professionals questioned their necessity, demonstrating a lack of awareness regarding the socio-cultural factors that often hinder women's participation in fields such as engineering and ICT.

The STEM education officers (EOs) team’s vision encompasses curriculum transformation, STEM educator support and professional development, STEM popularisation and policy making (Science Centre, n.d.). The Science Centre organises various activities for primary and secondary as well as STEM educators to enhance scientific literacy and promote STEM subjects and careers (Science Centre, n.d); while the specific activities may vary in content, their aim is to engage primary and secondary school students with science.

The Interactive Science Centre - Esplora provides a platform for inquiry-based non-formal science education. This approach aligns with contemporary pedagogical practices, facilitating active learning and engagement. Esplora is operated by the MCST under the Science Popularisation Unit, and was launched in 2016 (Times of Malta, 2016). Its objective is to promote science communication and stress its importance in today’s society (Esplora Interactive Science Centre, 2022). Their mission is “to ignite a passion for questioning, investigation and discovery”. It actively seeks to cultivate a culture for questioning, investigation and discovery for all visitors and staff so that they can explore, think, imagine, appreciate, and ultimately create (Esplora Interactive Science Centre, 2022a).

Esplora launched the National STEM engagement group in 2020 after the National STEM engagement conference in 2019. Its mission is “bringing together professionals from different sectors of STEM education to discuss and plan measures related to STEM learning and outreach” to avoid duplication and fragmentation (Esplora Interactive Science Centre, 2024). Its 2019-2022 road map includes twenty measures to draft a National STEM engagement strategy.

Esplora has also recently hosted its first science festival “Esperimenta tikka xjenza,” targeting residents from the south of Malta. The event was held in July 2022 at the historical Birgu Couvre Porte, highlighting science in citizens’ daily lives and the fact that science can be fun and accessible regardless of gender, ethnicity, level of education, and socioeconomic status (Esplora Interactive Science Centre, 2022b). Other activities by the national STEM engagement group targeted various audiences, from primary students to primary educators, science practitioners, and a Masters course on science in STEM education and engagement.

Although both institutions target the same age groups, they do not collaborate, resulting in potential repetition and a fragmented approach. Another example is the two National STEM awards, one organised by the former Directorate for Learning and Assessment Programmes (DLAP) (targeting educators) and one organised by the Interactive Science Centre (targeting educators and other STEM professionals). Furthermore, the success of these events is self-proclaimed, and no official evaluation was conducted.

Two surveys were commissioned (in 2014 and 2019) by Esplora and were conducted by the Market Intelligence Services Company Limited (MISCO) to gauge citizens’ level of awareness with respect to science and provide insight into science communication at a local level (MISCO International Ltd., 2019).

Data was collected through telephone interviews, and 400 responses were collected where a 70% quota was set on age, gender, education, and region (MISCO International Ltd., 2019). In both surveys, respondents expressed interest in science, registering an increase from the 2014 survey, with age and level of education as possible factors affecting their interest. While there is an increase in people’s motivation to know more, they still find the subject difficult to comprehend. This survey's most popular scientific themes were related to health issues and scientific discoveries (MISCO International Ltd, 2019). It is important to note that this survey reports that the respondents believe their influence is very limited in affecting legislation about scientific issues, although they do believe this should not be the case. Another significant finding is that the internet is used to gain information about science and technology (MISCO International Ltd, 2019).

1.8.3 Media and science communication in the Malta Islands

Science literature and data related to the relationship between media and science on a local scale is limited. MCST’s 2006 report states that science and technology and their appreciation in the media are limited to international channels such as the Discovery Channel (MCST, 2006). Combining science and entertainment, known as edutainment, is an opportunity for science communication to reach out to a broader audience. Despite its ability to attract a broader audience, it has been argued that edutainment may compromise scientific and pedagogic values in favour of entertainment (Niemann et al., 2020).

Scientific coverage of Maltese media can be found in print, such as articles on ongoing, groundbreaking, and innovative research. Topics tend to revolve around health and the environment. Kerr's study (1992) notes that there is usually an explosion of coverage of an environmental issue whenever it arises, followed by a saturation point. This tends to happen with certain specific topics, while other topics, such as hunting and trapping, are always a concern for citizens (Kerr, 1992). Similarly, in the current climate, transportation and pollution are always issues of public concern, and numerous articles have been written on these topics. Both health and environmental issues appear to be the most pertinent to society; however, other topics are often perceived as less important. This is mainly due to their complexity, making it challenging for reporters, scientists and science communication practitioners to communicate effectively. For example, radiation pressure seems like a complicated term, but it is the concept that light can exert a minuscule force on objects.

Sounds of Science, launched in 2016 by UM staff members, is published weekly to highlight local and international scientific research that is made accessible to a broader range of society. This page is published weekly in the Sunday Times of Malta (Newspoint, 2016). Journalists claim their role is to inform citizens and not educate (Lewenstein, 2015). Locally, journalists do not typically specify in a particular area, such as science, leaving scientists and researchers to write scientific articles. Several University academics and researchers have written various scientific articles in newspapers related to the environment (e.g. (Deidun, 2022), space (Caruana, 2019) and health (Marmara, 2021).

The University of Malta publishes THINK, its research magazine, which highlights the stories of students, alumni, and researchers (Think Magazine, 2022). The magazine was previously published as Research Matters and rebranded as THINK after one issue in 2011 (UM, 2011). The magazine aims to explain research conducted at the University in simpler terms and raise awareness among citizens by disseminating information about research being conducted at the UM.

In Malta, online news portals dominate (65%) over traditional television as the primary news source (52%), with social media platforms and blogs overtaking television (55%) (European Parliament, 2022b).

Television is still a popular medium among Maltese citizens - programmes that contain scientific discoveries and discussions are rare. "X-lab" was a popular educational show launched at the UM in 2008. 26 episodes were filmed in Malta and Cyprus and aired on Television Malta (TVM) and Education 22. These shows were translated from Maltese to English (Times of Malta, 2008). Each episode consisted of children from 13 different schools demonstrating a scientific principle by conducting an easy-to-do experiment that can be done at home using everyday material. The topics covered ranged from aerodynamics to Artificial Intelligence (AI) and DNA. Although visual media is meant to entertain, some programmes tend to misrepresent science, such as the case of the TV programme "Xplaħħ malħajt", aired in 2012 and financed by MCST. On the other hand, "X-lab" was still entertaining and educational without misrepresenting or perpetuating false information and stereotypical portrayals of who conducts science.

The latest TV programme "Ġina u l-Esploraturi" was launched in 2021, where children learn about science in various scenarios: the kitchen, weather, arts and science together with Ġina and her Esploraturi friends (Esplora Interactive science centre, 2022c). Other scientific material is infused in discussion programmes or documentaries such as "Natura Maltija" on Television Malta.

While radio is declining in popularity worldwide, science shows are almost non-existent in Malta. Like television, science on the radio tends to be disguised under specific topics such as health and the environment (Bugeja & Weitkamp, 2009). Bugeja's short radio series "Science on the Air" on Campus FM was a fifteen-minute science-based radio programme in the Maltese language.

In 2015, I launched "Radio Mocha Malta" which showcases international and local scientific research in Malta in Maltese. This was aired on Radju Malta 2, Radju Malta and Campus FM. The programme hosted local and international researchers who discussed scientific research technology and development. Shortly after, a video was shot and uploaded to the Facebook page to reach an online audience with hundreds of views. Health-related programmes remain very popular, with the video about a nurse discussing stroke prevention and diagnoses uploaded to Radio Mocha Malta's Facebook page reaching nearly five thousand views.[6]

Another radio series launched on Campus FM in 2022, "Riċerkaturi," explores stories about researchers and their research who are receiving funds from the Research Innovation and Development Trust (RIDT). This show highlights how scientists have chosen this career path and organisations and individuals who donate funds to research conducted at the UM.

Locally, social media platforms such as Facebook are still quite popular, but they are increasingly popular with the older generations, while Instagram and TikTok are more popular with Gen X and Gen Z generations (Kemp, 2022). It needs to be explored whether such platforms are ways for local citizens to actively engage with science and technology.

[6] Video can be seen here: https://www.facebook.com/RadioMochaMalta/videos/165285051072726

As already stated, information on science and technology in the local media is quite limited and, at times, erroneous. However, this section tried to give a snapshot of the local community's representation of science and technology in Maltese media.

1.8.4 Local policy documents

Shifting focus from the representation of science and technology in Maltese media, it is imperative to delve into the local policy documents, which offer significant insights into science education and engagement strategies. Drafting strategy and policy documents takes on different approaches framed by a multi-faceted nature in the quest to achieve its aims and the related trade-offs that come with it (Hili, 2017). Communication between policymakers and other stakeholders is essential and needs to be a two-way process where policymakers pay attention to what other stakeholders can contribute (Hili, 2017).

There are two major approaches to policy implementation: top-down and bottom-up. While there have been attempts to move away from this dichotomy, this field remains highly undertheorised (Bache et al., 2015). The top-down approach involves policy decisions taken by the central government (Sabatier, 1986), which tends to neglect other actors and stakeholders (Sabatier, 1986).

Sabatier's analysis includes six conditions for the top-down approach:

- whether the policy objectives were clear and consistent;
- whether policy was adequate to ascertain causal assumptions;
- the legal structures needed for officials to enhance compliance;
- skilled officials at implementation and use of resources;
- maintaining constant support by interest groups and sovereigns throughout the process; and
- recognises the changes in socio-economic differences. (Sabatier, 1986, p. 24-25).

Conversely, the bottom-up approach identifies the network of actors or stakeholders involved and considers what they want to achieve (Sabatier, 1986). The local, regional, and national actors are included in the various aspects of the relevant programmes through the network's contacts. Both perspectives hold value in this study, as each offers unique insights. This study examines how the government and its entities approach a potential policy regarding PES, and the varying impacts this policy would have on different levels, including the public sphere.

Although science education policies and strategies, like the National Curriculum Framework (NCF) (2012) and National Education Strategy (2024-2030) (Government of Malta, 2023; Government of Malta, 2012) are well-established, local science engagement or popularisation strategies are lacking. The 2011 NCF's science vision (Government of Malta, 2011) introduced the concept of coordinated science but left stakeholders in academia, trade unions, the government and teachers divided. While some were for the coordinated approach to approach, others favoured adequate preparation for the separate sciences at advanced levels (Times of Malta, 2007). The unsuccessful endeavour to introduce the idea of coordinated science to students interested in non-STEM subjects highlights a missed opportunity to potentially alter the mindset and perceptions of science and technology to create an educated PSS among future citizens.

Higher education has slowly developed in small states, and students are often forced to pursue their studies in larger states with more robust economies (Baldacchino, 2011). While science communication policies are non-existent in small states, their educational policies recognise the need for positive, participatory action and solution-centred approaches to education and learning, especially in climate change (Crossley et al., 2011). This is a prevalent topic relevant to all countries, especially islands that are more vulnerable to the effects of climate change (United Nations Framework Convention on Climate Change (UNFCC), 2005). The efficacy of educational policies in smaller states to effectively address the dynamic power shifts and incentivise citizens to engage with national scientific and technological issues remains a topic of considerable academic debate.

In 2009, the MCST released a report outlining its vision for research and innovation (R&I) from 2007 to 2010 (Bugeja & Weitkamp, 2009). The strategy aimed to establish the necessary infrastructure for R&I and emphasised a science popularisation approach that involved ongoing communication with education stakeholders such as parents, teachers, students, and career professionals (MCST, 2006). Other plans included science journalism through television and radio programs, showcasing researchers and scientists by recognising their achievements, updating state education institutions with multimedia educational material, establishing science and technology parks for youth, and promoting science hotspots in new infrastructure projects (MCST, 2006). However, the updated 2020 R&I strategy, published in 2014, failed to mention public engagement or science popularisation (MCST, 2014). The interactive science centre was launched in 2014 and opened to the public in 2016, with a funding of 26 million Euros, 12 million of which were financed by the EU (Times of Malta, 2014). It appears that the science centre was intended to activate the science popularisation strategy outlined in MCST's R&I document in 2006.

The Malta Chamber of Scientists (MCS) expressed concern that science often remains marginalised within Malta’s policy agenda. In response, MCS released a document in 2016 outlining a vision for a national science policy aimed at strengthening Malta’s economy and advancing science as a strategic priority (Malta Chamber of Scientists, 2016). This document outlines an inclusive vision for a cohesive science policy that will impact positively across the Maltese economy and will help ensure its continued prosperity. By identifying key issues and proposing solutions, this document provides a blueprint for the future of science in Malta. The document explores four pillars: public engagement, education, research, and national investment. For public engagement, MCS argues that an appreciation of science needs to be instilled in different groups within society, engaging a wide range of stakeholders from schoolchildren to business leaders to policymakers. In terms of education, the framework asserts that students need a better science education to decrease the number of schoolchildren leaving early. The third pillar, research, implores how research is the basis of a good economy and ensures economic growth. The final pillar implores for nationwide investment using targeted strategies. Furthermore, MCS claims that these pillars will work towards an informed democracy, scientific excellence and economic growth that results from having a highly educated and scientifically literate workforce (MCS, 2016).

The National Skills Council held a conference in 2023 to bring together various stakeholders and address the challenges and opportunities related to skills development in Malta. The conference resulted in six key recommendations developed in collaboration with the stakeholders (National Skills Council, 2023). These include:

1. Prioritising empowerment and well-being of individuals.
2. Recognising transversal and basic skills as essential areas for development.
3. Encouraging Continuous Professional Development (CPD) to improve competencies.
4. Focusing on Digital Literacy, Green initiatives, and Active citizenship.
5. Enhancing lifelong career guidance by establishing a National Career Guidance Network.
6. Ensuring access to training for team members to support continuous learning, with employers taking a pivotal role in promoting this culture.

1.9 Conclusion and research questions

In conclusion, the review of literature conducted in this study has illuminated various dimensions of PES and its implementation across diverse contexts, grounded in the evolving definitions and interpretations in the history of science. The study's objective was to identify the relationships and power dynamics associated with PES in Malta, with an investigation conducted to comprehend the underlying connections between stakeholders in PES entities. Given Malta's investment of significant resources, energy, and funds, it is crucial for the nation to examine and understand various initiatives and activities organised by different entities conducting PES. These events are often sporadic and fragmented, resulting in wasted resources, repetition, and gaps in the areas being addressed. This analysis aims to determine whether a Maltese PES strategy could potentially unite different sectors and entities for a more cohesive approach, breaking away from the hegemonic forces exerted by stakeholders. To achieve this goal, the following research questions will be explored:

1. What are the specific structures, formats, policies, stakeholders, actors, and relationships associated with PES in the Maltese Islands and other countries?
2. What are the underlying goals and objectives of the organisations and entities that perform PES in the Maltese Islands and other countries?
3. To what extent does PES in the Maltese Islands respond effectively to individual and societal needs?
4. Looking at the international scenario, to what extent could a national strategy for PES integrate science communication with the different dimensions of science education (i.e. formal, informal, non-formal)?

Chapter 2

Methodology:

A mixed-method approach to data gathering

2.0 Introduction

This chapter will first investigate the theoretical framework that guided the overall approach. Various theories are adopted to analyse the public sphere in terms of PES. The public sphere in this study will follow the Habermasian approach, where citizens are given the opportunity to engage and participate in discussions and critical debates. While Habermas was concerned with the discourse that takes place before formal structures have formed (Feinstein, 2015), this study will focus on participation and discourse in both formal and informal structures. Citizens' engagement with informal and non-formal aspects of science within the formal structures was investigated.

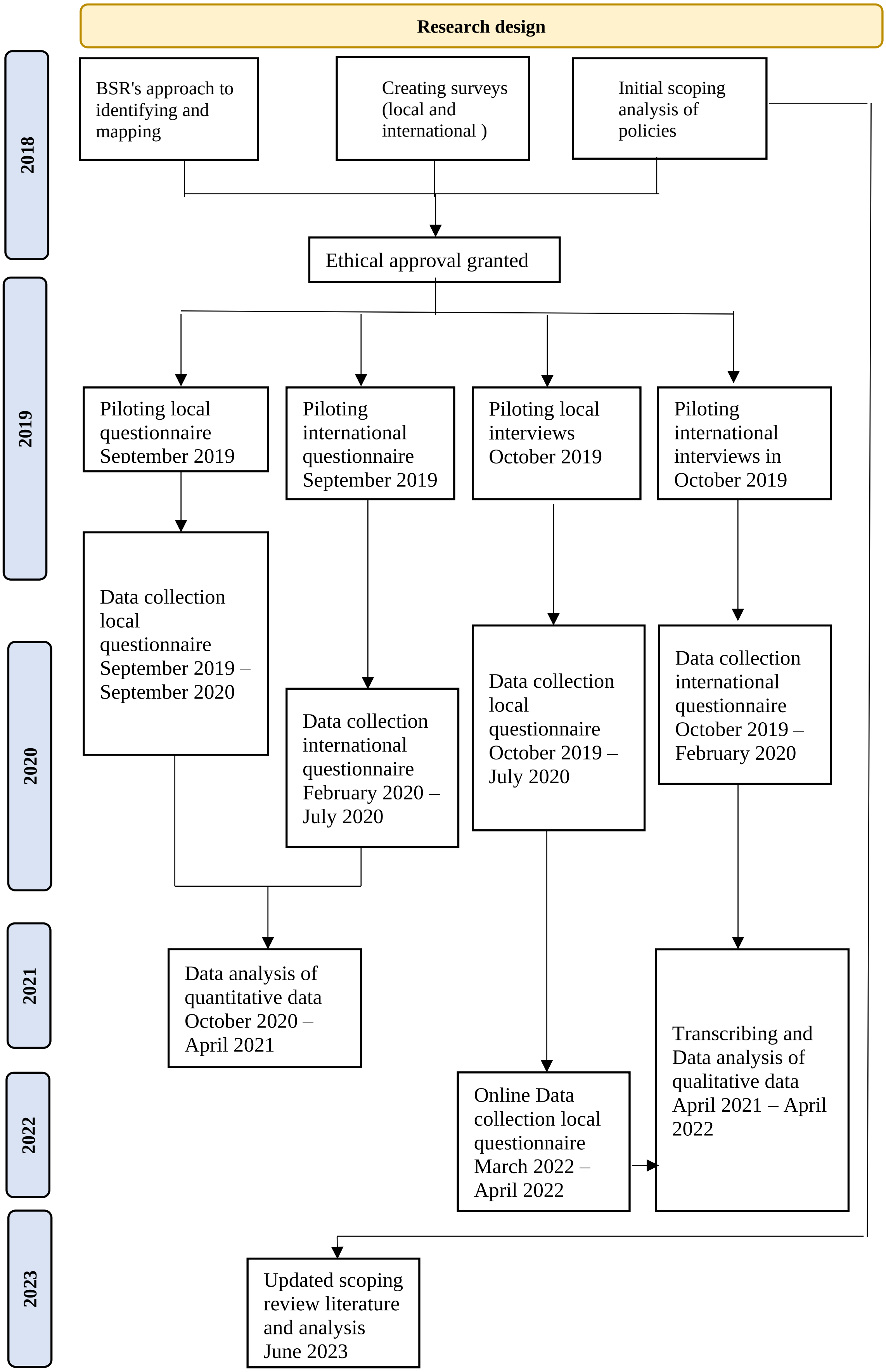
The relationships of PES in Malta were explored through Bourdieu's theoretical lens of the capital. However, the concept of science capital, as developed by Archer et al. (2015), was also considered in this study to explore whether this type of capital could be applicable to this study. Through the concept of the public sphere, as coined by Habermas this study will further explore the context of the public sphere of science (PSS). In tackling the first research question, stakeholder theory proposed by Freeman et al. (1984, 2010) was adapted and applied to this study to identify and investigate stakeholders' role in PES. The approach was taken from Business for social responsibility (BSR). The reason for using this approach was to ensure that the stakeholders identified for this study were appropriate in tackling the set research questions. The steps in identifying the stakeholders are explored in greater detail in section 2.2.1.

The chapter will then focus on how my study gathered data through a mixed-method approach to investigate the first three research questions. Following the design of the methodological tools used for this study, the material was sent for ethical approval, pilot tested, and data collection ensued. Epistemological knowledge was gathered through quantitative and qualitative data between 2019 and 2021. The quantitative data was then analysed using statistical analysis, and the qualitative data was analysed using thematic and content analysis.

In tackling the fourth research question, this study investigated international PES strategies and policies to explore how regulations can anticipate and address cultural and societal needs, institutional structures, and national strategies. Furthermore, these strategies give an overview of the current trends in how citizens engage with science. The entire research design of this thesis can be found in Figure 2.1.

Figure 2.1:

The timeline of the thesis research design



2.1 Theoretical framework guiding the overall approach.

2.1.1 The pragmatic approach

Worldviews, also referred to as paradigms, epistemologies and ontologies, or broadly conceived research methodologies, are described "as a general philosophical orientation about the world and the nature of research that a researcher brings to the study" Creswell, (2014, p.6). The philosophical worldview proposed for this study is pragmatic due to my educational background, involvement in PES events and activities, hosting and founding a radio show, and my current role as a science communicator at the UM. Remaining aware of my subjectivities, I mitigated against possible biases by acknowledging them, keeping an open mind, and corroborating results through a mixed-method approach to data collection.

"Dewey and other pragmatists called for a different starting point that was rooted in life itself—a life that was inherently contextual, emotional, and social" (Morgan, 2014, p.1047). Dewey sought to emphasise the role of human experience in promoting pragmatism (Morgan, 2014). For Dewey, beliefs and actions come together to create meaningful experiences. Certain decisions are made consciously but happen in a semi-automated state - described by Dewey as habit. However, inquiry calls for self-conscious decision-making that always happens in a specific context. In this respect, inquiry beliefs that require clarification are examined, and appropriate action is taken. Since pragmatists see the world in various ways, researchers tend to adopt mixed methods, which gather data using many approaches for data collection and analysis (Creswell & Creswell, 2018). For this research study, different methodological approaches were adopted to explore, understand, and map the science communication landscape in Malta and capture information from a variety of stakeholders.

2.2 Stakeholder theory

Stakeholder theory is a technique used and adapted for the scope of this study to shed light on the purpose of organisations and their responsibilities towards their stakeholders with respect to PES within the PSS. It was taken from BSR, an organisation which works with leading companies for a healthy and sustainable planet (Morris & Baddache, 2012), making such an approach suitable to this study and in line with the RRI framework and the SDGs. Furthermore, the CEO Water Mandate encourage using the BSR's five-step engagement approach towards engaging stakeholders to "initiate and sustain constructive relationships over time and throughout their organisation, creating shared value by engaging early and often" (UN Global Compact, n.d.). As explored further in this chapter, publics are seen as stakeholders emphasising shared value and constructive relationships in PES within the PSS.

ANT is another approach to understanding the relationships between publics. Referred to as actants or actors in PES, the main publics considered for this study were human actants rather than non-human ones. While ANT's advantage lies in considering inanimate actors during interaction analysis, in the case of the PES landscape in Malta, this theory will serve as an extension to stakeholder theory to describe non-human actants, such as the role of technology, that play a role in the PSS (Sayes, 2014).

2.2.1 Stakeholder engagement strategy

This study followed the BSR's Five-Step Approach to stakeholder engagement (see Figure 1.5). Figure 2.1 summarises the entire process, and the research design is explored further in this chapter.

1. Engagement strategy

1.1 The first step was *to identify the history of PES initiatives* held by various local institutions over the years. This included pinpointing local PES events, activities, documents, policies, and strategies together with whom and for whom they were created. The stakeholders were first identified and then differentiated through the stakeholder engagement strategy based on the key criteria: expertise, willingness, and value in creating a possible future PES strategy. The ones identified for this study included people grouped in organisations, entities, or networks such as government entities and ministries, citizens, NGOs, companies in industry, universities, schools, and the media.

1.2 The second step within the engagement strategy was *to set the level of ambition* for this study and the stakeholders involved. This step ensured that there were no misunderstandings between the goals of this study and the stakeholders. This study's goal was to collect data from various stakeholders in a transparent manner by communicating the reasons for data collection.

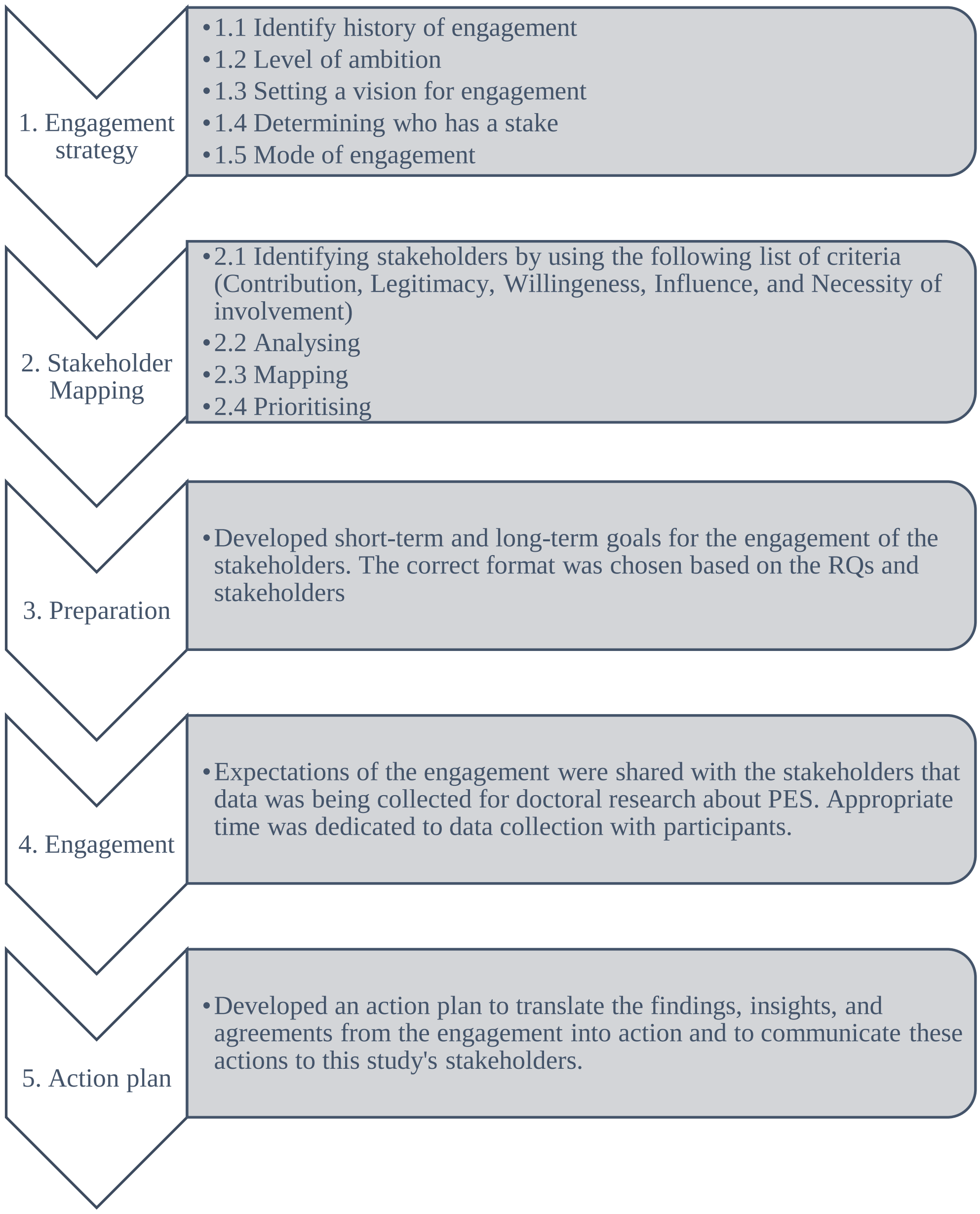
1.3 The third step was *to set a vision behind engagement*. This study's priority was to understand what stakeholders' involvement and relationship with science is in the PSS. In this step, it was important to prioritise engagement and understand the scope of this study to identify and address any potential boundaries or barriers that might hinder the process.

1.4 The fourth step was *to define filters to choose the stakeholders relevant to this study*. This is a broad stakeholder engagement process and further detail can be found in Step 2 (Stakeholder mapping) of the Five-Step Approach.

1.5 The fifth step in the engagement strategy was to *identify the tactics needed to engage with the stakeholders*. Although it would have been ideal to record citizens' discussions around science that happen at various places, including homes, this approach was not feasible.

Figure 2.2:

The approach adopted for the study adapted from the BSR's five-step approach



2. Stakeholder mapping

This step was important to identify the key stakeholders for this study and where they come from. The most effective approach was to build on the engagement strategy as developed in Step 1.4. From this, a final list of stakeholders was created based on the following four phases: identifying, analysing, mapping, and prioritising as part of the stakeholder mapping process.

Step 2.1 Identifying

To ensure a thorough approach, pertinent personnel in the PSS with key insights into PES were consulted and solicited for input. Following this, stakeholders involved in PES across the Maltese Islands were identified through a brainstorming session.

Step 2.2 Analysing

Once the list of stakeholders was identified, further analysis was conducted to better understand their relevance and perspective to this study based on:

- **contribution** explored what the stakeholder has to offer in terms of advice, information, or expertise on PES within PSS;
- **legitimacy** investigated the stakeholder's claim for engagement and whether the stakeholder has enough reason to engage;
- **willingness** explored how willing the stakeholders were to engage with this study.
- **influence** identified the role stakeholders play as to who they influence and how much influence they have with PES in the PSS; and
- **necessity of involvement** identified stakeholder's need for involvement as otherwise, they would derail or delegitimise the process if they were not included in the engagement process of this study.

The BSR's 5-step approach aligns with the theoretical frameworks of Habermas (1974), Bourdieu (1986), and Archer et al.(2015), offering a comprehensive lens for understanding stakeholder engagement. Habermas (1974) emphasises the importance of rational, inclusive discourse, ensuring all stakeholders, regardless of power, have equitable opportunities to contribute and influence. Bourdieu (1986) highlights structural inequalities, highlighting how the distribution of economic, social, cultural and symbolic capital shapes willingness, legitimacy, and influence in engagement processes, often privileging those with more significant resources. Archer et al.(2015) complement these perspectives by focusing on stakeholders' reflexive agency, demonstrating how individual actors navigate and assess structural and cultural constraints to determine their role, contributions, and necessity of involvement. The theoretical ideologies by Habermas (1974), Bourdieu (1986) and Archer et al. (2015) complement the BSR approach by integrating normative ideals of equity and fairness with practical considerations of power dynamics and individual agency, offering a robust foundation for evaluating and improving participatory practices.

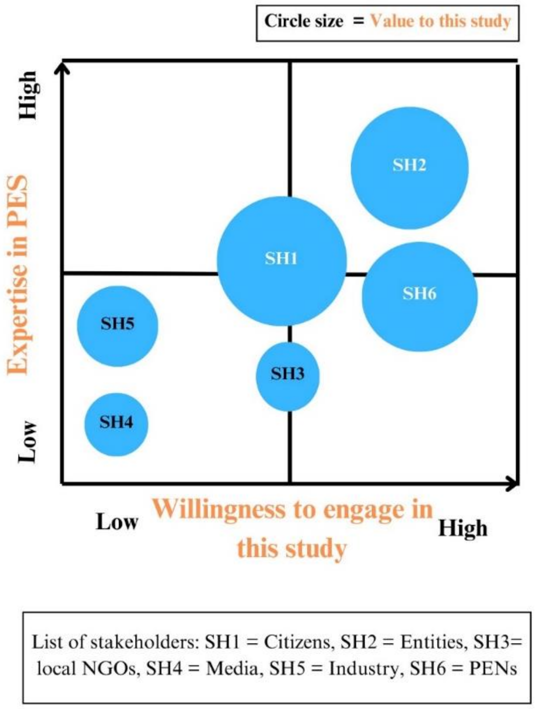
These five criteria in the BSR's five-step approach were used to create and populate a visual chart as in Figure 1.5 in the first chapter.

Step 2.3 Mapping

The next step involved visually mapping stakeholders (see Figure 1.7). The final visual representation adapted for the scope of this study can be found in Figure 2.2.

Figure 2.3:

Final visual representation of stakeholder mapping



Step 2.4 Prioritising

Prioritisation was an important step in this study as it was not possible to engage with all the stakeholder groups with the same level of intensity. Citizens, institutions involved in PSS conducting PES in Malta and international science communication organisations were considered for this study.

The major focus of this study was to emphasise the bottom-up approach where citizens' experiential knowledge was given importance and value within PES in the PSS. Citizens were chosen as they are continuously affected by science and technology in their daily lives, from what technology to use to whether to take a vaccine or not. PES conducting entities have a significant impact on the attitudes, beliefs, and actions of citizens in regard to their engagement with science. Therefore, they were identified as a crucial stakeholder in this study. The way entities engage citizens with science is paramount to understanding citizens' involvement and participation in science.

While the media and industry are important to study, the willingness to engage with this study was on the low side. Due to a lack of information, accessibility, and limited role regarding how citizens engage with science, the industry and media stakeholders were not considered for data collection. I want to emphasise that my eight years of experience hosting a radio show, which aimed to make science, research, and technology accessible to audiences without a scientific background, has given me valuable insights into the limited availability of relevant content on television and radio. Furthermore, the first chapter includes a brief overview of the media content related to PES. I believe that with little to no information concerning these two stakeholders, an in-depth study needs to be undertaken to fully understand their role in the local PES scene. Literature about local and international science communication/education strategies and policies was consulted.

I expanded my Ph.D. research to include the international perspective of evaluating the structure and the effectiveness of international science communication organisations by being engaged as a researcher on an international EU research project called Responsible Research and Innovation Globally (RRING). At present, there exists a gap in the establishment of local networks for science communication. This could provide added advantages in the form of global knowledge that can be utilised in the local science communication arena.

3. Preparation

This step aimed to focus on the available resources to define the rules of engagement with the chosen stakeholders. It was important to set strategies on how best to communicate the need for the chosen stakeholders to gather their feedback and take part in this study. Different strategies were chosen based on the type of data collection (e.g., online, in-person).

4. Engagement

This step included going through the necessary planning steps for successful engagement with the stakeholders chosen. During the data collection process, it was necessary to train data collectors to ensure the collection of the most data possible while maintaining validity. This step was crucial to ensure that the data collected was reliable and accurate.

5. Action plan

One crucial step in stakeholder engagement is the identification of opportunities from feedback. This will help to determine actionable steps, revisit goals, and plan future steps towards addressing the feedback and future engagement.

2.3 Strategy and policy documents

The formulation of strategy and policy documents may utilise various approaches influenced by their multifaceted nature to accomplish their objectives while also making necessary compromises (Hili, 2017). Communication between policy-makers and other stakeholders is essential and needs to be a two-way process where policy-makers pay attention to what other stakeholders can contribute (Hili, 2017).

Implementation of policies takes on two major approaches: top-down and bottom-up. While there have been attempts to move away from this dichotomy, this field remains highly undertheorised (Bache et al., 2015). The top-down approach to policy-making is characterised by the centralisation of decision-making power within the government, often at the expense of other actors and stakeholders. While this approach can be effective in providing a clear focus and preliminary assessment of policy effectiveness, especially when resources are limited, it may fail to capture the dynamics of certain publics and their diverse needs. Moreover, the top-down approach runs the risk of oversimplification and neglects the nuanced interactions between different publics.

On the other hand, the bottom-up approach to policy-making aims to identify the network of actors and stakeholders involved in the policy-making process and consider their perspectives and goals. This approach is inclusive and responsive to the specific needs and circumstances of the public, often leading to greater buy-in and commitment to implement policies (Sabatier, 1986). By empowering publics and giving them a voice and authority in decision-making processes, the bottom-up approach fosters greater cooperation and collaboration among local, regional, and national actors. However, bottom-up approaches can be time-consuming because of extensive consultation and consensus building and risk fragmentation if different stakeholders have conflicting interests or priorities. This approach also requires significant resources such as time, money, and expertise to facilitate inclusive decision-making processes. Numerous scholars have acknowledged the imperative need to integrate top-down and bottom-up approaches and have made concerted efforts to synthesise the two (Sabatier, 1986; Goggin et al., 1990).

My interest lies in exploring the different effects this policy would have at various levels, including the PSS. To achieve a comprehensive understanding of the subject matter, an integrative approach was adopted to conduct the study. This involved collecting data from various stakeholders using a bottom-up approach. The rationale behind this was to involve and empower citizens, which can lead to novel approaches and solutions that may not have emerged from a top-down approach. Furthermore, senior management from entities conducting PES were consulted through interviews. This approach could potentially equip policymakers with valuable insights to make informed decisions that align with the needs and expectations of society. In this study, both top-down and bottom-up perspectives are relevant as they offer valuable insights into how the government and its entities are approaching a potential policy on PES.

2.3.1 Scoping literature review

An initial online scoping literature review was conducted to find common themes and priorities between national documents in different countries that relate to or mention public engagement with science or science communication. The stages of a scoping review include: identifying the research question and relevant studies, study selection, charting the data and collating, summarising and reporting the results (Arksey & O'Malley, 2005).

Formulating and implementing a protocol is a crucial step in enhancing the impartiality of the review process. Tranfield et al. (2003) advise providing a description of the steps followed to address the research question, the study sample, the information gathered, and the inclusion and exclusion criteria. The following protocol was devised for international national documents, as summarised in Table 2.1.

Table 2.1:

Literature review protocol for national documents

Phase	Description
1	Definition of the purpose of the literature review. Develop the research questions. Identify the mode of collection
2	Develop a search strategy – Include search period, inclusion criteria
3	Selection process – create a list of keywords and various combinations. (See Table 2.3). Identify limitations
4	Identify national documents through inclusion and exclusion criteria (See Figure 2.4)
5	Choose how documents are going to be analysed – Reflexive analysis

The goal was to understand how countries across the globe involve citizens with PES in national science communication documents or documents related to science, research, and technology. This review aimed to answer the following research questions:

- How are the frameworks, strategies, policies and laws structured in different countries?
- What are the common themes, and priorities between the national documents in different countries?

2.3.1.1 Search strategy

Data collection started in 2018 and then updated in 2023 to include the latest national documents. An initial screening was conducted to remove documents that did not mention any aspect of science communication. To be included in the analysis, documents had to:

- be national documents created by the government;
- include a global international perspective;
- mention PES – to highlight the role of engagement with science, rather than simply science as understood in the scientific sphere;
- have an English translation – otherwise it would not be possible to analyse the text;
- be easily accessible online
- provide a general overview and not be topic-specific e.g. health;
- be the latest version of the document; and
- a cut-off date 2023

2.3.1.2 Selection process

A combination of keywords used can be seen in Table 2.2. The documents were screened based on the inclusion criteria already stated. The terms were then refined through an iterative process throughout this scoping review. Some of the national documents were found through snowball sampling (see Figure

2.3). Members from national science communication organisations such as RedPop and AAAS were consulted when documents were difficult to find. Other national documents were identified through other documents such as articles and peer-reviewed papers that appeared in the original search. National governmental websites were also consulted and considered to identify national documents.

2.3.1.3 Limitations

Limitations of this literature review included the language the document was written in. At times, official translations of these documents were not available, such as documents from Latin American countries. To counteract this other official documents or peer-reviewed papers were consulted and used as grey literature. Despite a thorough search, certain documents were still not available, such as the new law that Mexico passed in May 2023. As a result of the scarcity of national documents pertaining to PES, the present review was not amenable to a more comprehensive and systematic literature review.

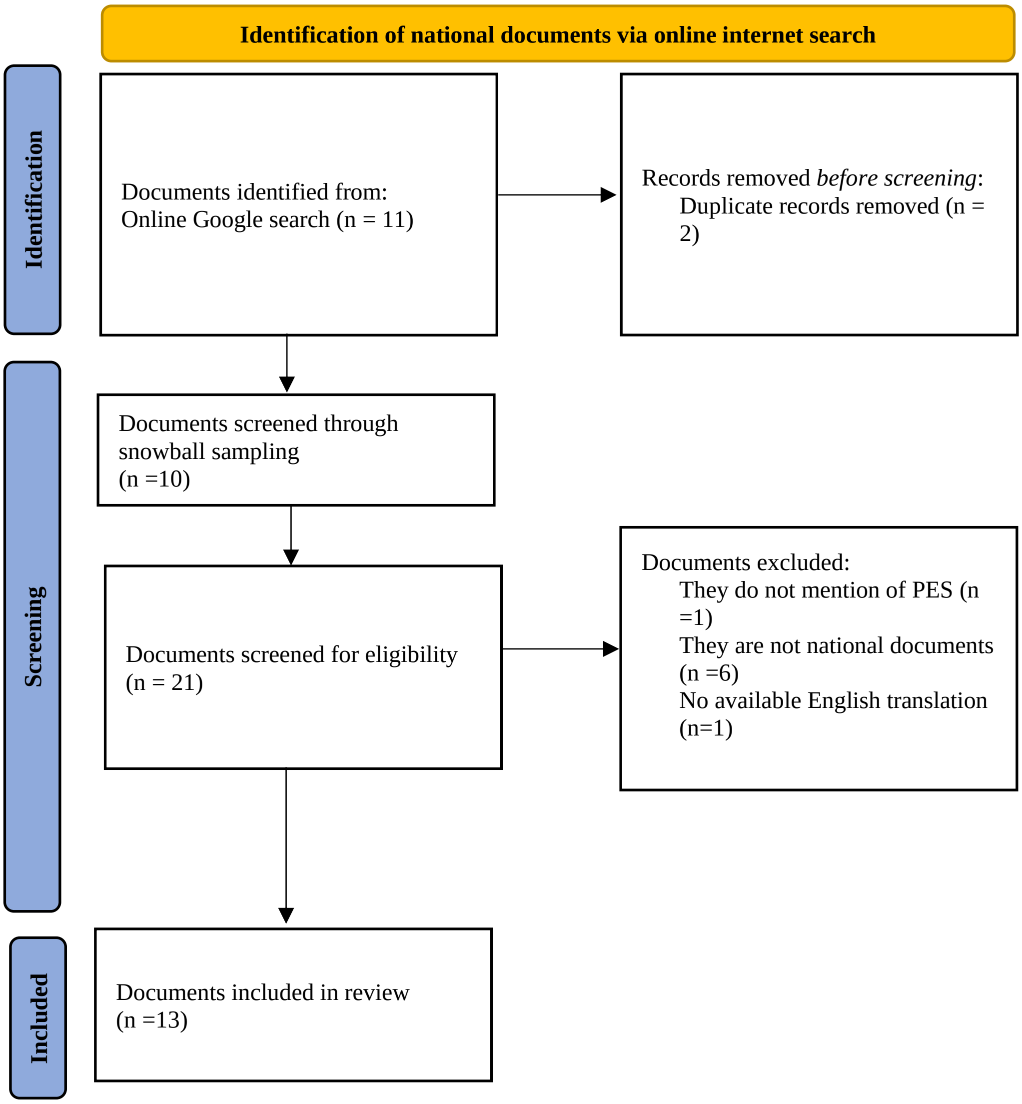
Table 2.2:

List of phrases used for the online search.

Phrases used for the online literature search	**Variations of the phrase**
National science engagement Policy documents	Strategy, frameworks, law instead of Policy
National science communication Policy documents	Strategy, frameworks, law instead of Policy
Research and Innovation policy	Research and innovation national strategies Research and innovation strategy
National science open access documents	
National public engagement documents	
National Policy on Science, Technology & Innovation	
National strategy science engagement	
White paper on science technology and innovation	
Public engagement strategy	
National science and technology documents in Latin America	
National science communication documents Latin America	
Science and technology policy	Names of different countries e.g. Argentina

Figure 2.4:

Flowchart of the identification of national documents



2.3.1.4 Document analysis

After the selection of documents (n=13), a document analysis was performed (see Figure 2.3). Document analysis is an effective method that involves the selection of data from already available sources, which can be more efficient and faster than gathering new data from scratch (Bowen, 2009). The present mode of analysis, which involved the utilisation of online documents, has proven to be a cost-effective and efficient technique. Furthermore, this method has demonstrated its suitability for repeated reviews, given the stable nature of the documents involved (Morgan, 2022; Bowen, 2009). On the other hand, documents can provide insufficient detail – such as the actual processes and steps in creating the final document (Morgan, 2022). It was also difficult to retrieve certain documents in English, and there are potential documents that may not be available in the public domain. Despite these potential issues, document analysis provided this study with insights into the role that PES plays in official national documents outside of the Maltese Islands.

The steps involved in analysing the documents involved, superficial and thorough examination followed by interpretation (Bowen, 2019). In the first step, superficial examination, relevant passages of text were identified based on whether the document mentioned interactions with citizens at various levels of engagement, be it dissemination or more participatory approaches. Another round of examination was conducted to identify the relevant texts based on the involvement of citizens with science. Thematic analysis was then used to conduct an analysis of the identified documents due to its ability to identify, analyse and report themes within the documents (Braun & Clarke, 2006). Themes in this context reflect 'a pattern of shared meaning, organised around a core concept or idea, a central organising concept' (Braun et al., 2019, p.3). For this study, reflexive analysis was utilised as a fully qualitative approach that prioritises contextual or situated meaning, multiple realities, and my subjectivity as a resource, rather than a limitation (Braun et al., 2019). At the beginning of the process, the coding was flexible and adapted as the documents were reviewed, allowing for a comprehensive interpretation based on the gathered data and the strategies identified.

2.3.1.5 Identifying themes

The following sub-questions were addressed to identify the themes in the final list of national documents.

- Is it a policy, strategy, policy brief, white paper, framework, or law?
- Who are the publics mentioned in the document?
- How are the publics mentioned in the document involved within PES?

The themes and domains were identified using the reflexive thematic analysis approach, and they are included in the results section.

2.3.1.6 Quality assessment

The sources used for this review were government databases, official reports, and policy documents. Documents created by science councils or organisations that were not linked directly with national governments were excluded from the final review but were only used as grey literature.

2.4 Acquiring epistemological knowledge

Appropriate research design is needed "whenever we wish to generalise from our findings, either in terms of the frequency or prevalence of particular attributes or variables or about the relationships between them" (Oppenheim, 1992, p.5). The combination of quantitative and qualitative research methods has proven effective in various research areas, including human development and program evaluation. This approach involves applying both methods to produce comprehensive findings. Weisner and Lieber (2010) have emphasised the benefits of using a variety of research methods, including this integrated approach. While various definitions of mixed methods exist (Creswell, 2010), the following definition will be used for this study:

> … the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the purposes of breadth and depth of understanding and corroboration. (Johnson et al., 2007, p.123)

Creswell & Creswell (2018) consider both methods as a continuum rather than distinct methods to be used in one scenario or another. Convergent mixed methods offered my research the possibility of collecting both forms of data at roughly the same time, and the information was then integrated into the interpretation of the overall results (Creswell & Creswell, 2018). The strength of mixed methods lies in the diversity of ideas, although researchers using mixed methods run the risk of using inconsistent terminology or duplicating ideas, to name a few, resulting in greater chaos (Tashakkori & Teddlie, 2010). On the other hand, Tashakkori and Teddlie (2010) highlight that quantitative and qualitative methods complement each other, with the use of text, words, and language through qualitative methods and numbers, tables, and statistics through quantitative methods. A mixed-method approach provided this study with a multilayered research approach that was distinct from what quantitative or qualitative methods alone could have offered.

A mixed-method approach was adopted to gather local data. Data was gathered from citizens through a quantitative questionnaire, while qualitative data was collected through interviews conducted with people in senior management positions related to PES at various entities. This approach was taken as it also assists with validating findings through triangulation (Morgan, 2017), encouraging greater confidence in reaching scientific conclusions (Weisner & Lieber, 2010). However, Silverman, (2006) warns against using triangulation as an approach to reaching an 'objective' truth as accounts and actions are rooted in different contexts. Furthermore, this approach tends to ignore other stakeholders' perspectives and places emphasis on the social scientist's role in reaching conclusions. Therefore, when interpreting the data, care was taken to infer conclusions rather than generalisations.

Exploring the opinion of public engagement with science networks (PENs) was very important to this study, as it informed how the role of theory and practice in the international science communication field can facilitate effective science communication on a local scale. Local science communication organisations are either non-existent or are theme-based organisations (example focusing on the environment or astronomy) and conduct some PES activities. Acquiring an international perspective on

PENs will help address this lacuna in the local Maltese PES scene. Exploring the effectiveness of PENs meant that different methods were needed to understand the multi-faceted aspects of PENs by examining what members need from PENs, and how they are governed and managed. A mixed-method approach was also undertaken where a quantitative survey was created, and data was gathered from members of international science communication organisations. Interviews were also conducted with some of the presidents and directors of these international PENs. By triangulating data through various methods, including quantitative citizen questionnaires, interviews with senior management in entities that conduct PES, and members' questionnaires and interviews with senior management in PENs, a more comprehensive and holistic understanding of the local PES scene and the effectiveness of international PENs was obtained. This approach allowed for a more rigorous analysis, providing a more accurate depiction of the situation, and strengthening the overall validity of the study.

2.5 The quantitative survey – Local questionnaire

2.5.1 Questionnaire design and pilot testing local questionnaire

To analyse the current PES situation in Malta and answer the third research question, a questionnaire was designed to gather the attitudes and perceptions of Maltese residents. Willis (2019) proposed that the choice of instrument is dependent on two factors: whether it produces the correct information and whether it allows for data collection from the right stakeholders.

A questionnaire can cover various modes of collection, including self-administered, structured interviews and can contain checklists, attitude scales and rating scales (Oppenheim, 1992). A questionnaire was chosen as the instrument to gather information from citizens over the age of 18 as it is the best way to gather data from a large population (Oppenheim, 1992). There are three main reasons for measurement in quantitative research, also relevant for this study: it allowed for an explanation of fine differences between people, gave a consistent way of measurement, and allowed for correlation analysis (Bryman, 2016).

While descriptive questionnaires are not designed to show causal relationships between one variable and another, they indicate how many members of the population have a particular opinion (Oppenheim, 1992). Most of the questions were closed-ended. Only one open-ended question asking citizens what they think of ‘science’ was included. Close-ended questions were used because they are easy to administer and complete by participants and easier to process and analyse (Jensen & Laurie, 2016; Bryman, 2016).

The questionnaire contained three sections. In the first section, participants were asked to fill in demographic data: age, gender, current hometown, nationality, highest education qualification, and whether they belong to any NGO. Demographic data was used to define the sample and compare it to other variables.

The second section included questions about citizens' attitudes towards science. These questions asked what they think about science, their interest in science, and whether they have ever worked in a science-related field. This section provided a snapshot of the respondents' interests in relation to science.

The third section asked citizens about their level of engagement with science. Questions asked about whether they had attended activities/events related to science, and their frequency. Another two questions included their preferred learning medium and entities to learn about science. The final question asked how well informed they felt about science. This question was purposely-recording citizens' self-perception as it indicates how confident they feel about science. The Likert scale is a multiple-item measure of a set of attitudes relating to a particular area (Bryman, 2016). Respondents had to choose from a Likert scale for the last three questions, ranging from Strongly Agree to Strongly Disagree with an option of Prefer not to say, ensuring uni-dimensionality (Oppenheim, 1992).

The questionnaire and the consent form were sent to the University Research Ethics Committee at the University of Malta once the questionnaire was finalised and approval was obtained in September 2019 (see Appendix 1). Following the approval from the ethics board, a pilot survey was distributed between the 11th and 17th of September 2019. Nine responses from different ages, gender, and work backgrounds were collected, and feedback was sought from the respondents about the questions asked (Jensen & Laurie, 2016; Creswell, 2014). The final questionnaire was then distributed at various events that ranged from scientific to cultural festivals. The questions were uploaded on an online platform (ZOHO survey) and an offline questionnaire was also available for the participants to fill in on tablets and mobile phones. The information sheet, consent form, and the questionnaire can be found in Appendix 2.

2.5.2 Data collection and sampling

Physical responses were collected at four events (see Table 2.3) ensuring a wide distribution of people attending scientific and non-scientific events.

Two volunteers who were briefed on how to collect the data, assisted data collection. For each potential participant, a brief introduction was given, and consent was sought. Systematic sampling was used as it was easier to gather data from events (Jensen & Laurie, 2016). While random sampling is preferred in reducing the risk of human bias, systematic sampling involves selecting citizens directly from the identified events (Bryman, 2016). To standardise data gathering and minimise bias, one in ten people observed were approached to fill in the survey (Jensen & Laurie, 2016). The tablet was given to the random participant upon confirmation that they were over eighteen and resided in Malta.

Since Maltese residents are bi-lingual, most of the respondents felt comfortable filling out the English version of the survey. The Maltese version of the survey was given when participants were not comfortable with filling out the questionnaire in English. Participants had the opportunity to fill in the questionnaire themselves or have the questions read out to them, taking the form of an assisted interview. The collection of data took the form of an informal conversation, especially with older citizens, and citizens who were not able to read and/or write.

The data collected was used for triangulation with the data gathered through Esplora's published results (MISCO International Ltd, 2015; 2019). The demographic data obtained from the quantitative questionnaire was compared to the 2019 demographic data of Malta and Gozo, as provided by the National Statistics Office (NSO, 2014). This comparison ensured a representative sample and enable the inference of conclusions from the findings (Bryman, 2016). The bigger the sample, the more representative it is likely to be if the selection of the sample was randomly chosen (Bryman, 2016).

The questionnaire was then distributed during three other events (see Table 2.3), ensuring a wide distribution of people attending science and non-science events. Queues at Notte Bianca were targeted as potential ways of collecting data as there were long queues to visit certain sites.

Table 2.3:

Number of responses collected from four events

Event[7]	**Date**	**Number of completed responses**
Science in the City	27th September 2019	129
Notte Bianca	5th October 2019	34
Birgu Fest	12th October 2019	50
Natalis Notabilis	13th December 2019	49

Data Sampling

Regrettably, in 2020, physical data collection was not possible anymore due to COVID-19 health restrictions. A risk mitigation plan was devised and the decision to continue with online data collection was considered the best way forward. Minor cosmetic adjustments were made to create an online version of the questionnaire. The online questionnaire was made available from the 29th of August 2020 till 30th September 2020 and was distributed on various popular Facebook pages and groups in Malta. Through convenience sampling, local Facebook pages and groups with a good following (such as *Is-Salott* with over 13 thousand members) were targeted. Although less desirable, convenience sampling was employed to reach a large number of Facebook users for this study (Creswell, 2014; Jensen & Laurie,

[7] Science in the City is a science and arts festival that takes place in Valletta, the capital city. Notte Bianca is one of Malta's biggest annual arts and culture festivals and is held in Valletta. Birgu Fest is a festival of light that illuminates Birgu's winding medieval streets in the South of Malta. Natalis Notabilis is a Christmas market that is in the west of Malta (Rabat).

2016). Convenience sampling involves selecting respondents based on their availability and accessibility. Snowball sampling was also employed in this study, where participants voluntarily shared the questionnaire with various people through their personal Facebook and WhatsApp accounts. This mode of sampling relies on finding a good contact who can forward and distribute the questionnaire to other contacts (Jensen & Laurie, 2016). The risk with using these sampling techniques is that the results are not representative of the target population (Jensen & Laurie, 2016). To account for this, measures were taken to ensure a final representative sample. To compensate for the non-random nature of the data collection methods (through events and online via social media platforms), a representative sample was obtained by stratifying the sample according to gender and age. A better representative sample was acquired through a paid Facebook advert to increase the number of male responses between the 9-13th September, and another advert was used to reach out to both genders over the age of 65. Although convenience sampling and snowball sampling are less desirable than other sampling methods, such as random sampling, these methods were necessary to ensure a broad range of participants.

2.5.3 Data analysis

The quantitative data was cleaned and inputted in IBM SPSS Statistics 26. Statistical tests were then conducted to analyse the data. Various tests were selected depending on the data type of the outcome being analysed and the probability distribution (Jensen & Laurie, 2016). The chi-squared test was used to investigate the association between two categorical variables, such as NGOs/science festivals and museums and frequency of attendance. The Friedman test was used to compare mean rating scores between several related statements, such as the preference for learning about scientific developments and research. Since the data was ordinal and categorical, one-way Anova could not be used to acquire the p-value. The Kruskal Wallis test was used to compare mean rating scores provided to a statement between several independent groups that are clustered by age, gender, etc. The open-ended questions were analysed using thematic analysis. The Results chapter will further explore the rationale of each specific test.

The following hypotheses were chosen for the citizen questionnaire:

1. Demographic data such as gender, age, education, etc., are contributing factors to determining citizens' interest in science.
2. Citizens' learning preference to learn about science development and research through various sources such as the internet is a necessary but not sufficient condition to determine citizens' interest in science.
3. Citizens' learning preference to learn about scientific developments and research from different entities is a necessary but not sufficient condition to determine citizens' interest in science.
4. Citizens' membership status in local Maltese science-related NGOs is an indicator of their interest in science.

5. Citizens' perceived information about science, technology and innovation indicates citizens' interest in science.

2.5.4 Refusal Log

Refusals to fill in the questionnaire mostly consisted of people who did not have time or did not feel like they could help as it was about science or did not feel like filling in the questionnaire. The data shows a normal distribution of ages and genders except for the older [55-64 and 65+] age group. Other refusals were because they were not Maltese citizens or settled here.

2.5.5 Limitations

No data was collected from events held in Gozo due to the COVID-19 pandemic. A limited number of data collectors restricted the amount of data collected at the physical events. It was not possible to engage other data collectors due to availability, and limited time to brief and train them. However, many responses were still collected, and ultimately, a representative sample was acquired. The online survey had certain limitations, including the challenge of maintaining a refusal log, limited access to the internet for a portion of the population, and exclusion of participants who were unable to read or write. Additionally, the online questionnaire did not capture extra information obtained through informal conversations. However, these limitations were partially addressed by already collecting almost half of the sample through physical data collection.

2.6 International questionnaire

2.6.1 Designing and piloting the international questionnaire.

Information on the members' involvement, paid or otherwise, in PENs was collected through a quantitative survey. A questionnaire was selected as the data collection method to investigate whether these organisations help their members in improving the implementation of PES and to gain an objective perspective on this specific social reality (Bryman, 2016). As data comparing members' satisfaction from PENs was not available, this questionnaire was an exploratory way to understand this perspective. To ensure a wide variety of PENs, a selection of global, European, trans-national, and national networks research and practice communities in the field of science communication were considered (see Table 2.4). An online questionnaire was designed to collect data from participants involved in these PENs, as members or as non-members. This method of collection was chosen so that the questionnaire was available to an international audience and could easily be shared online. A self-administered questionnaire was cheaper and quicker to administer and removed interviewer bias (Bryman, 2016). It was convenient to fill in for respondents from different time zones. A limitation of this questionnaire type was that respondents were unable to seek immediate feedback if they felt the need while completing the questionnaire, which increased the risk of missing data and lowered response rates (Bryman, 2016).

This survey aimed to assess thoughts, feelings, attitudes, and values behind participants' involvement in PENs, be it through a paid membership or otherwise. The questions were designed following a literature search about the effectiveness in network theory (Farrugia et al., 2022). The quantitative survey design took place from October through December 2019. Some of the presidents and executive directors of PENs were asked to give feedback on the initial survey statements and questions. This approach ensured that the questions were relevant to their organisation/members and to encourage presidents to share the questionnaire with their members. However, not all the presidents provided feedback on the questions. While a mixture of close-ended and open-ended questions was created, close-ended questions were preferred as they are easier to administer and complete (Jensen & Laurie, 2016). In certain instances, open-ended questions enabled participants to answer freely (Jensen & Laurie, 2016), such as providing reasons for leaving a network.

This 21-item online questionnaire included the following sections: (1) General information - Demographics, (2) membership activity and commitment, (3) introduction and motivations to join a network, (4) ability and potential contribution to the network, (5) likert scale questions about model, structure, management of networks, (6) likert scale questions about communication and participation between the network and its members and (7) network retention. These thematic sections were based on factors highlighted in network theory on how effective organisations were in retaining their members and their own survival.

Table 2.4:

A selection of PENs consulted for the study

Network	**Type of network**				**Type of members**				
	Global	**European**	**Trans-national**	**National**	**Science communication practitioners**	**Science communication researchers**	**Interested in science shops**	**Working in science centres / museums**	**Science journalists and related fields**
Public Communication with Science and Technology (PCST)	●				●	●			
The International network for science shops, Living Knowledge	●						●		
European network of science centres and museums (Ecsite)		●			●			●	
European Federation for Science Journalism (EFSJ)'s		●							●
Association of Communicators in Education and Science (AKSON)				●	●	●			
Network for the popularisation of science and technology in Latin America and the Caribbean (Redpop)			●		●	●			

The purpose of the *general information* section of the questionnaire, was to collect demographic data that provided a snapshot of the population that PENs were made up of. The second section, 'Membership, Activity and Commitment', included questions about the respondents' involvement in PENs and whether they were paying members of any PENs. The third section included two other questions about where respondents learned about the PEN and their motivation to join that PEN, giving an indication of membership recruitment. The fourth section included two questions to rate the respondents' potential and current contribution to the PEN and to provide indications of members' level of participation within the PEN. To capture the perceptions, attitudes, and beliefs about how PENs operate and are managed, a 7-point Likert-type scale was used for the fifth section making the data easy to analyse using inferential statistics (Jensen & Laurie, 2016). The sixth section included Likert scale statements about how the network communicates at the management level and with its members. Another question explored respondents' preferred communication channels to communicate with other members. In both the fifth and sixth sections, Likert statements were randomised within each of the scale questions to address order bias. To account for respondents who exhibit response sets, which is the tendency to consistently reply in the same manner to each statement (Bryman, 2016), a combination of positive and negative statements was selected. The seventh and last section asked respondents to state whether the PEN was ethical. The final section asked respondents about what would attract them to stay in a PEN for the long term, whether they have ever left a PEN and the reasons for leaving. The final question asked about what keeps them from joining other PENs.

Ethics approval of the international quantitative and qualitative data was given by the University of College Cork, which led the RRING project. Pre-survey testing was conducted between October and December 2019. Ten participants from international PENs and Maltese NGOs were involved in the testing phase. The objective was to ensure that the questionnaire was easy to read and fill and free from double-barrelled questions or statements (Jensen & Laurie, 2016; Bryman, 2016). Feedback on each section and question was provided through an open discussion (Jensen & Laurie, 2016; Creswell, 2014). The questionnaire was translated into Russian and Spanish by third-party translators to broaden its reach. The information sheet, consent form and English questionnaire can be found in Appendix 3.

2.6.2 Data collection of the international questionnaire

Data collection of the international questionnaire started in February 2020 and ended in July 2020 through Qualia Analytics online platform. The consent was acquired from all the participants, who were also informed about the implications of participating in this questionnaire. Various distribution strategies were used across different platforms to ensure a wide reach for the final survey. This was ensured by using stratified random sampling and splitting the sample into different categories (Jensen & Laurie, 2016), mainly geographical spread, type of network, and whether it is a PEN. Distribution strategies included having the survey shared on the PENs' mailing lists through the presidents and senior administrative members, Ecsite's magazine SPOKES, and the PENs social media platforms - Facebook, Twitter, and LinkedIn. The survey was also shared on RRING's and International Consortium of Research Staff Associations (ICoRSa)'s Twitter accounts and my personal Twitter account.

2.6.3 Data analysis of the international questionnaire & limitations

The hypotheses were developed before analysis to reduce the risk of re-writing the script once the analysis has been completed (Dienlin et al., 2020). The hypotheses below were chosen as the study was designed to explore reasons for what motivates members of PENs to engage with their organisation actively and willingness to contribute even financially. Once data collection was finalised, the statistics software tool IBM SPSS Statistics version 26 was used to conduct several non-parametric tests due to the relatively small sample size.

The hypotheses created for this survey to analyse the quantitative data were the following:

1. Ability to contribute is a necessary but not sufficient condition for the members' involvement and effectiveness of paid PENs;

2. Gender, age, and career path are contributing factors to members' involvement in paid PENs;
3. The structure and model used for networks may be contributing factors for members' involvement and effectiveness of paid PENs;
4. Frequency of communication channels is an indicator of members' involvement and effectiveness of PENs;
5. Involvement in PENs is a necessary but insufficient condition for people to become paid members of PENs.

While parametric tests tend to have more statistical power, non-parametric tests are recommended with small sample sizes (Van Buren & Herring, 2020). Descriptive statistics were used to measure and identify general patterns in the sample data to help understand the specific data's features and provide short summaries about the sample. Statistical tests were chosen based on the type of variable, be it ordinal, nominal or interval. Ordinal variables are categories that can be ordered according to rank, as opposed to nominal variables, also called categorical (Bryman, 2016). Interval/ratio variables are those variables where the distances between the categories are identical across a range.

Other tests used were chi-square, Wilcoxon, Friedman, crosstabs, and Kruskal Wallis tests. The Wilcoxon signed rank test was used to compare the mean rating scores provided to two related statements, such as the potential against the current PEN contribution to the PENs. The Shapiro-Wilcoxon test determined whether a score distribution was normal or skewed. The Friedman test was used to compare mean rating scores between several related statements, such as statements related to the potential to contribute to the network. The Kruskal Wallis Test was used to compare mean rating scores provided to a statement between several independent groups clustered by age, gender, and other demographic data. The rationale of each specific test is further explored in Chapter 4.

The limitations of the international quantitative survey included limited resources such as people translating the questionnaire to other languages, a Euro-centric data sample, and a relatively small final sample size. While several strategies were employed to acquire a higher final sample size, respondents still did not fill in the questionnaire. Non-parametric tests were used to account for a small final sample size. However, the sample could not be stratified based on individual networks due to a low response rate from the individual networks. The final questionnaire was only available in English, Spanish and Russian.

2.7 Qualitative data - Interviews

Qualitative research is a strategy that emphasises words rather than quantification of data collection and analysis. However, it does not necessarily mean that quantitative data generation or collection does not take place (Bryman, 2016). It is broadly inductivist, constructionist and interpretivist, although researchers may not apply all these three features (Bryman, 2016). An inductivist view takes on the approach that theory guides and generates research, and an interpretivist or epistemological position examines through the interpretation of its participants. In contrast, an ontological position, also referred to as constructionist, is where social properties are embedded within individuals' interactions, constructing social realities (Bryman, 2016).

Through opportunistic and snowball sampling local interviews were conducted with people holding senior management positions related to PES in the following entities: the University of Malta, the Malta Council for Science and Technology (MCST), the Malta College for Arts, Science and Technology (MCAST), and the Ministry for Education, Sport, Youth, Research, and Innovation (MEYR). All these entities contribute and have the power to determine how citizens view and whether they engage with science. Through face-to-face interviews, my study was able to gather an understanding of how and at what level entities engage citizens with science.

Internationally, interviews were conducted with presidents and/or executive directors of PENs to inform whether PEN strategies to engage their members were effective and sustainable for the organisation and its members. In both cases, in-depth information was required, where interviewees' representation and accounts of their personal views and opinions were given (Silverman, 2006).

2.7.1 Designing and pre-testing interviews with members of Maltese entities

Semi-structured interviews were conducted with senior members of local educational and entities that conduct PES. The flexible nature of semi-structured interviews allows unexpected themes and insights to emerge. This mode of interview allowed me to ask and probe further during the interview in response to the interviewee's responses (Bryman, 2016). Face-to-face interviews were chosen so that aspects of the research could be explained without affecting other participants and understand the participants' thinking and knowledge of the current PES local scene (Jensen & Laurie, 2016).

The first question was concerned with identifying and understanding what drives local research and innovation policies within each respective institution and how these drivers are prioritised. The second, third, fourth and fifth questions dealt with the channels of communication used by their entity together with the respective strategies of their expectations, mode to communicate and how to engage various stakeholders. The following two questions dealt with the topics Maltese society is engaging in versus what they personally think that society should engage in. The eighth question asked whether their staff receives training with respect to engaging citizens with science. The ninth and tenth questions explored the role and stake the Maltese government has in determining how the communication of scientific research and innovation occurs and whether different political parties have different policies about how science is communicated between and to different stakeholders. The final two questions explored the interviewee's personal vision against their entity's. The questions were designed to capture in-depth data about entities' motivations for PES.

Following ethics approval, the twelve open-ended interview questions were finalised, and pilot tested with three academics of diverse gender, age, and scientific backgrounds (Engineering, ICT, Statistics, and Operations research). Based on their feedback, it was decided that the first few interview questions would be sent to interviewees before the interview as these questions were based on facts. In contrast, the rest of the questions were based on their opinion of their role within the institution.

2.7.2 Data collection from Maltese entities

Interviews were conducted with key representatives of the following Maltese entities: the UM, MCST, MCAST and what was previously the Directorate for Learning and Assessment Programmes (DLAP) within the Ministry for Education, Sport, Youth, Research, and Innovation (MEYR). DLAP has transitioned to the directorate of the STEM and Vocational and Educational Training (VET) programmes. All the interviewees were involved in decision making roles within the various institutions that included directors, assistant directors, pro-rectors and lecturers; more detail about their specific roles would have revealed their identity. To protect the confidentiality of the interviewees, pseudonyms were created for each respondent (see Table 2.6).

Fifteen face-to-face interviews were conducted between the period of October 2019 and February 2020 after consent was given by all the interviewees. To have the current vision of all the institutions, four more interviews were conducted as the people interviewed at the time moved on to other roles or retired. Due to health regulations during COVID-19, these latter interviews were conducted on Zoom between March 2022 and April 2022, with one exception. All the audio recordings were then transcribed, except for the participant who sent her/his responses through email. The sample population (see Table 2.5) was found to have a skewed representation of interviewees from UM. Notably, despite efforts to contact the most senior management personnel, some declined to participate in the study. The audio recordings will be destroyed a year after the doctoral study is submitted. The final set of questions can be found in Appendix 4.

2.7.3 Data analysis from Maltese entities

Once the nineteen interviews were transcribed, thematic analysis was used. The intention was not to develop a grounded theory from the data set, and the sample was relatively small (Braun & Clarke, 2020). Repetition is one of the most used criteria to generate codes and identify themes, also referred to as recurrence in the data collected. Such a process must remain relevant to the study's research questions (Bryman, 2016).

As a first step, deductive coding was used to identify the four main themes and categories based on the interview questions (Braun et al., 2019). Through inductive coding, further codes were generated by analysing the text, followed by the interpretation of patterns leading to identifying the main themes. This provided a basis for a theoretical understanding, resulting in a theoretical contribution to the research questions (Bryman, 2016). The four main themes elicited were strategies and policies, institution and communication channels, education and training, and the entity's aims about PES. Chapter 5 contains all the themes, categories, and codes.

Pseudonyms were given to each of the interviewees to protect their anonymity (see Table 2.4). All were involved in decision-making roles within the various entities, including assistant directors, directors, lecturers, and pro-rectors; more details about their roles would have revealed their identities.

The limitations associated with the Maltese interviews were accessibility and availability to some of the senior management staff within the entities, although the final sample size still managed to have a broad spectrum from each entity.

Table 2.5:

Pseudonyms for Maltese interviewees

Institution	Pseudonym
MEYR	DLAP1
MEYR	DLAP2F
MEYR	DLAP3C
MCST	MCST1
MCST - Esplora	MCST2
MCST - Esplora	MCST3F
MCST - Esplora	MCST4C
UM	UM1
	UM2
	UM3
	UM4
	UM5
	UM6
	UM7
	UM8F
	UM9F
	UM10C
	UM11C
MCAST	MCAST1

2.7.4 Data design and sampling for the international interviews

Interviews were conducted with the senior management of 11 PENs to gain in-depth knowledge about the management structure and network structure of international PENs. The interviews also provide greater assurance of the validity of the findings from the quantitative survey (Jensen & Laurie, 2016).

Based on the project's underlying aims, the literature developed by an expert group in the Horizon 2020 project RRING was used to develop the questions (Dalton et al., 2020). As already highlighted, these interviews provided information on whether effective PENs can serve as a potential model for the Maltese landscape. The semi-structured interview included the following sections: structure, management, governance, funding, membership, network creation/evolution, and inclusiveness and diversity of membership.

The questions in the first section aimed to gather general information about the interviewee's role and work within the PEN. This included demographic data, their role within the PEN, whether they are directly involved in PE and whether they have involved people outside of the organisation with the PEN. The following section included questions about the management and governance of the network to capture information about the operations, as well as the variety of roles within the interviewee's PEN. The subsequent section explored the funding sources of the PEN, including its funding model. Questions about membership of the PEN followed this section. Questions included whether the number of members affected the PEN, as well as strategies employed by the PEN to attract and retain new members. Other questions were about members' communication channels and ways to keep good relationships among members within PEN. The following section sought to understand the motivations behind establishing the PEN and examine whether there has been a need to modify its structure over the years. Questions included the PEN's evolution of their communication channels and defining what a successful PEN means to them. The last section included questions about inclusivity within the PEN, including questions about diversity, such as the issue of women in STEM. The final set of questions can be found in Appendix 5.

Pre-survey testing was conducted with presidents and senior management of Maltese NGOs in October 2019. This ensured the questions were concise and clear (Jensen & Laurie, 2016).

Table 2.6:

Pseudonyms and information on PENs

Pseudonym	Founded	Aims of the PEN	Role of interviewee within the PEN
Global Network 1	1994	This PEN is an international science and education program that focuses on promoting scientific literacy and building connections between people passionate about the environment. Students, teachers, researchers and lifelong learners can connect with the program’s global community.	Director
Global Network 2	2001	This is the formal international network of Science Shops and Community Based Research.	Co-ordinator
Global Network 3	1989	The international PEN seeks to promote new ideas, methods, intellectual and practical questions, and perspectives on the communication of science and technology.	President
Global Network 4	2004	An international scientific community that ignites, enables, and celebrates scientific excellence and science-informed decisions and actions and has a specific centre on public engagement.	Director
National Network 1	2016-2022	A former national network connecting people working in science communication	President
National Network 2	2004	A national network promoting science communication, awareness and understanding in science and science communication	President
National Network 3	2014	The PEN aims to promote Science Communication in all its aspects, to promote the exchange between Science Communication professionals, and to promote the informed participation of citizens in all issues involving Science and Technology.	President
EU Network 1	1989	Connects science centres/museums, research bodies, private companies, festivals professional networks and other organisation in science engagement	Executive Director
EU Network 2	2001	This network connects public engagement professionals in the fields of research, innovation, and education. Members can be individual experts or established organisations with a common goal of involving societal actors in the lifecycle of knowledge creation.	President
EU Network 3	1986	This PEN aims to ensure communication with stakeholders in the university strategic planning	President
Trans-national Network 1	1990	Science communication network of centres and programs in Latin America and the Caribbean	Executive Director

2.7.5 Data collection of the international interviews

Once consent was obtained, data was collected online via Skype or Zoom between October 2019 and February 2020. This mode of data collection was favoured over face-to-face interviews, as all the interviewees lived in different countries, making it easier to schedule and collect data online. The audio and video recordings were stored on an external hard drive to facilitate transcription. These will be destroyed a year after the doctoral study is submitted.

2.7.6 Data analysis of the international interviews

Content analysis was used to analyse the interviews. It is defined as an approach which analysis documents and texts in various forms seeking, to quantify content based on predetermined categories conducted in a systematic and replicable way (Bryman, 2016). It is also flexible and allows use in various contexts (Bryman, 2016). While content analysis tends to reduce the data into fewer content categories, reliability problems are associated with the different variations of what words mean, definitions given to categories, or coding rules set by the coder (Weber, 1990). However, having an external coder provided an opportunity to discuss the coding. The codebook was refined so that the definitions of the codes were clear to both coders.

After the audio files were transcribed, an initial deductive step was taken to explore patterns related to effectiveness at the network and community levels. Subsequently, a codebook containing main categories and sub-categories was created.

The subcategories for the network level theme were: 1) governance structure, 2) management and leadership, and 3) policies. The subcategories for the Community level theme were 1) values of the network, 2) membership, and 3) stakeholder diversity. When the codebook was created, an external coder used the codebook to apply the codes to the transcriptions using the qualitative software Atlas.ti.

To achieve reliability, two human coders were used (Weber, 1990). Content analysis relies on three types of reliability: stability, reproducibility, and accuracy. To achieve stability and rule out inconsistencies over time, the content was coded more than once by the same coder. Having more than one coder achieved reproducibility. Krippendorf's alpha coefficient was used as an inter-coder reliability test to achieve accuracy.

During inductive coding, further sub-codes emerged. Once the codebook was finalised, an external coder applied the codes to the transcriptions on the desktop version of Atlas.ti. Once the documents were coded, Krippendorf's alpha coefficient was measured to check the agreement between the two coders (Krippendorf, 2017). The documents were coded twice to ensure a reliability index of 0.667 or higher (Friese, 2021).

The qualitative survey's limitation was that only two coders were available to code the qualitative data. To ensure reliability and account for this limitation, coding was done twice.

2.8 Conclusion

This chapter highlighted how a mixed methods approach was undertaken to develop a stronger understanding of the research problem. The unique aspect of this type of approach was that it provided a way to understand the diversity of Maltese publics and the stakeholders involved in the local PES scene. The international PEN knowledge adds potential applications to the local science communication scene. The next chapters explore the results of the quantitative and qualitative aspects of the data collected

Chapter 3

Scoping literature review:

International documents about public engagement with science

3.0 Introduction: Final list of documents

This chapter analyses the national documents of 13 countries spanning over five continents, chosen as described in Chapter 2 (see Table 3.1) to address Research Question 4. Three themes were identified: Drivers for national documents and stakeholders/publics, Education and Training, and Funding. The respective main categories and sub-codes are in Tables 3.2-3.5.

Table 3.1:

National documents related to PES

	Country	**Continent**	**Name of document**	**Type of document**	**Published**
			1st round		
1	India	Asia	Science, Technology, and Innovation Policy (STIP)	Policy	2020
2	Malaysia	Asia	National Policy on Science, Technology, and Innovation NPSTI	Policy	2019
3	Japan	Asia	White Paper on Science, Technology, and Innovation 2021	White paper	2021
4	South Africa	Africa	White paper on Science, Technology, and Innovation	White paper	2019
5	Zambia	Africa	National Policy on Science, Technology, and Innovation	Policy	2020
6	U.K. - Scotland	Europe	Public Engagement Strategy	Strategy	2021
			Snowball sampling		
7	Netherlands	Europe	Vision for science choices for the future	Strategy	2014
8	Ireland	Europe	Impact 2030 Ireland's Research and Innovation Strategy	Strategy	2022
9	Australia	Australia/Oceania	Australia's National Science Statement 2017	National statement	2017
10	New Zealand	Australia/Oceania	Te Ara Paerangi Future Pathways White Paper 2022	White paper	2022
11	Argentina	South America	Diagnosis and roadmap for an open science policy in Argentina	Policy	2022
12	Iceland	Europe	Science and technology policy 2020-2022	Policy	2022
13	China	Asia	Law of the people's Republic of China on popularisation of science and technology	Law	2002

3.1 Theme 1: Drivers for national documents and stakeholders/publics

Table 3.2 gives an overview of all the main categories and sub-codes for the PES drivers and the stakeholders/publics mentioned in these documents.

Table 3.2:

Main themes and sub-codes of Theme 1

Theme 1: Drivers for national documents & Stakeholders/Publics		
Main categories	**Sub-codes**	**Description**
1.1 Drivers for PES	1.1.1. STEM uptake and STEM careers	Whether STEM uptake and STEM careers are national drivers.
	1.1.2 Economic needs	Whether economic needs drive the country.
	1.1.3 Scientific excellence	Whether the country emphasises the need to produce excellent research to propel the country forward and to respond to global needs.
	1.1.4 RRI and community involvement	Whether the concept of responsible research and innovation and the goal of being inclusive, equitable, and seeking to involve the community within research serves as a driving force for countries.
	1.1.5 Media	Whether countries have a drive to influence the media.
1.2 Type of Stakeholders	1.2.1 Government	Refers to ministries and departments within governmental entities as stakeholders.
	1.2.2 Civil society	Refers to citizens in society as stakeholders
	1.2.3 Industry	Refers to companies in scientific research, development, and technology as stakeholders.
	1.2.4 Academia	Refers to knowledge creation in education, and at higher educational entities as sstaakeholders.
	1.2.5 Local authorities	Refers to local authorities as stakeholders that collaborate with government.
	1.2.6 Schools	Refers to stakeholders in compulsory education.
	1.2.7 Science centres and museums	Refers to interactive science centres and traditional science museums as stakeholders
	1.2.8 NGOs	Refers to NGOs that involve citizens with science as stakeholders.

Main category 1.1 Drivers for PES

Subcode: 1.1.1 STEM Uptake and STEM careers

Nearly all the countries considered in this study mentioned this driver as important for their country, except for China, Argentina, and Scotland, due to the nature of the document. While the common theme is the development of scientific talent and careers, the specific approaches, challenges, and priorities vary among the different nations.

Countries like Ireland (Government of Ireland, 2022), Zambia (Republic of Zambia, 2020), South Africa (Republic of South Africa, 2019), and Iceland (Government of Iceland, 2020) mention specific quantitative targets for various aspects of scientific education and research, such as the number of researchers, PhD graduates, or STEM subject graduates.

Iceland expressed their need "…to increase the number of graduates in science, technology, engineering, creative arts and mathematics (STEAM-subjects)" (Government of Iceland, 2020, p.54). Similarly, Zambia want "to strengthen and build the human resource capacity in Science, Technology and Innovation…promote the teaching and learning of science, technology, engineering, and mathematics (STEM)" (Republic of Zambia, 2020, p.12).

Furthermore, Japan also acknowledged the importance of STEM uptake through the "National Institute for Materials Science (NIMS) [which] is actively introducing its research to the public, particularly to young students who might become scientists in the future" (Japan's Ministry of Education, Culture, Sports, Sciences and Technology (MEXT), 2022, p.231).

The Netherlands, Ireland, Malaysia, Zambia, and Australia acknowledged the global competition for scientific talent and the need to attract and retain top researchers. The Netherlands emphasised "that scientific personnel should be able to pursue a full career based on excellent performance in education" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.65). However, Australia's document mentioned its concern about the decline in participation in school-level scientific literacy and mathematics and that they would be "unable to supply the skills required for the future workforce" (Australian Government, 2017, p.11). Furthermore, "enrolments in these subjects [are] at the lowest level in 20 years…[and the] performance in STEM subjects is also slipping (Australian Government, 2017, p.9).

Ireland aims to "attract the best students and research talent globally…learning from the best and gaining cutting-edge experience" (Government of Ireland, 2022, p.42). Malaysia highlighted that the student environment needs to encourage "creativity, risk taking, rewards market-driven ideas [which] will inspire interest in science and technology careers" (Government of Malaysia, 2013, p.9) so that it can flourish.

On the other hand, some countries, like Ireland, emphasised attracting global talent and offering an international experience (Government of Ireland, 2022, p. 2). While New Zealand also highlighted that the country needs to ensure "sustainable career pathways for Pacific Peoples" (New Zealand Government, 2022, p.10).

Zambia identified specific challenges, such as a bias toward arts and social sciences, “low capacity for research and development in Science Technology and Innovation (STI) as well as low use of ICT in schools. This has resulted in inadequate skills in technology and innovation” (Republic of Zambia, 2020, p.3).

Ireland and India (Government of India Ministry of Science and Technology, 2020, p.41) stressed the importance of inclusivity in career progression, considering academic age over biological age and embracing lifelong learning. Ireland wanted to increase the number of researchers towards “fully embracing lifelong learning” (Government of Ireland, 2022, p.39). New Zealand highlighted the importance of developing “new workforce career trajectories that enable more diverse and multidisciplinary and diverse career trajectories within academia and industries…to move in and out of other sectors while maintaining their links to the traditional RSI system” (New Zealand Government 2022, p.27).

Subcode: 1.1.2 Economic needs

All the documents in this study shared common themes of promoting knowledge, innovation, and economic growth. The specific economic needs, goals, and strategies vary based on each country's unique circumstances and priorities.

Ireland’s specific economic and social benefits include “new jobs, new companies, and an economy at the frontier of science and technology” (Government of Ireland, 2022, p.48). India claims that science, technology and innovation are “the key drivers for economic growth and human development” (Government of India Ministry of Science and Technology, p.2).

Many of the countries stressed the importance of knowledge, research, and innovation as key drivers of economic growth. They recognised that investing in research and innovation can lead to economic and social prosperity “with a view to solving societal issues or contributing to the public debate” (Netherlands’ Ministry of Education, Culture, and Science, 2014, p.40). Ireland also stated that a knowledge-based economy “will be central to long-term economic and social sustainability at national and regional level” (Government of Ireland, 2022, p.2). While Australia considers it to be “vital to ensure ongoing prosperity” (Australian Government, 2017, p.12).

Some documents discuss the need to transition from a factor-driven economy to a knowledge-driven economy, while others focus on maintaining strong economic performance. In Zambia its “largest share of Gross domestic product (GDP) in the manufacturing sector was generated from resource-based and low technology manufacturing” (Republic of Zambia, 2020, p.4). Furthermore, Zambia’s document stated that there has been an “improved performance of the economy largely driven by the following key sectors of mining, agriculture, livestock, health, manufacturing, energy and education” (Republic of Zambia, 2020, p.3).

Issues that South Africa faces are “inter-linked challenges of unemployment, poverty, and inequality...” (p.ii), with China’s document stating that “people’s governments at various levels shall incorporate it into their plans for national economic and social development...to create a good environment and favourable conditions for Popularisation of Science and Technology (PST)” (Ministry of Science and Technology of the People’s Republic of China, 2022, p.2).

Many countries committed to achieving specific economic targets, by increasing research intensity rates or gross expenditure on research and development (GERD) as a percentage of GDP. A commitment to increasing investment in research and development (R&D) and innovation was highlighted, with this financial commitment seen as essential for economic development.

Ireland boasted of its economic growth, “which has increased at a rate well above the EU average” (Government of Ireland, 2022, p.6). India aims to “double the number of full-time equivalent researchers, gross domestic expenditure on research and development and private sector contribution every five years” (Government of India Ministry of Science and Technology, p.6). Similarly, Malaysia wanted “to increase its gross expenditure on research and development at least by 2.0% by 2020 (Government of Malaysia, 2013, p.12). On the other hand, New Zealand’s business expenditure GDP has remained relatively unchanged “moving only marginally from 0.52% in 2010 to 0.56% of GDP in 2020” (New Zealand Government, 2022, p.18).

Subcode: 1.1.3 Scientific excellence

Each country’s national documents reflect its unique priorities and objectives in pursuing scientific excellence. Some common themes included the importance of researchers, international collaboration, excellence and quality assurance to support scientific progress.

Many documents, such as the Netherlands’, emphasised the importance of researchers and their pivotal role in advancing science and innovation and “are of immense importance to society... Science can be compared to top-level sport: a competitive undertaking whereby individual researchers attempt to outperform each other” (Netherlands’ Ministry of Education, Culture, and Science, 2014, p.10).

International collaboration in research and innovation was another aspect of scientific excellence. Ireland and Australia stressed the importance of participating in global research networks and being seen as preferred partners in international collaborations (Government of Ireland, 2022, p.2; Australian Government, 2017, p.13).

Japan stipulated a shared focus on pursuing excellence in scientific research and innovation where they want to "restore the world's highest level of research capabilities in order to realise Society 5.0[8] (MEXT, 2022, p.2). Similarly, 'Dutch science is notable for its broad spectrum of disciplines, with high performance in each (Netherlands' Ministry of Education, Culture, and Science, 2014, p.18), with Zambia establishing "centres of excellence for scientific and technology research (Republic of Zambia, 2020, p.14).

Iceland emphasised the role and importance of basic research as part of scientific excellence in society which "provides the foundation for a society that fosters innovation, culture, welfare and democracy" (Government of Iceland, 2020, p.12). New Zealand places "the emphasis on individual disciplinary excellence and short-term outputs [which] fits uneasily alongside the need for more transdisciplinary research, more novelty and risk-taking in research, and more data-intensive research" (New Zealand Government, 2022, p.26).

Subcode: 1.1.4 RRI and community involvement

The key statements from national documents highlighted a commitment to diversity, open access, strategic planning, and societal engagement in science and research governance. Each nation contributes unique perspectives, reflecting a global commitment to advancing science for society's benefit.

Strategic planning takes centre stage in the Netherlands, emphasising the need for the "National Science Agenda [to be seen as] a living document, able to anticipate and respond to current developments. The entire agenda will, therefore, be reviewed and updated every seven years" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.39).

Similarly, Ireland complements this by embedding a culture of innovation in its public service through the 'Making Innovation Real' strategy; "the Irish public service will embed a service-wide culture of innovation and continue to deliver high-quality services to our citizens that are efficient, integrated, and inclusive" (Government of Ireland, 2022, p.17).

South Africa extends the focus beyond research and development "to a broader conceptualisation of innovation, and supporting a whole-of-society approach to innovation…to ensure that all policies related to innovation (e.g. trade, competition, education and procurement policies) work together to support innovation in South Africa" (Republic of South Africa, Department of Science and Technology, 2019, p.xi).

[8] Society 5.0 is a human-centered society where economic development and resolving social issues are compatible through an integrated system of cyberspace and physical space, aiming for sustainability, resilience, safety, security, and diverse well-being for individuals.

Australia also aims to develop science policies in which the "…government will recognise that science is fundamental to the economy and social wellbeing, and core to the mission of the government, as part of a multidisciplinary research ecosystem" (Australian Government, 2017, p.5).

In India, "the STI ecosystem needs a focus on delivering what is needed, which requires strong engagement with stakeholders (industry, academia, R&D labs and social actors). ...[to address] rural problems in the country" (Government of India Ministry of Science and Technology, 2020, p.26).

Societal engagement is a shared goal across nations. India pledges support for "citizen science projects, stakeholder consultations, co-creative experiences, and policy interventions will be supported." (Government of India Ministry of Science and Technology, 2020, p.44) Malaysia envisions science, technology and innovation (STI) contributing to "a stable, peaceful, prosperous, cohesive and resilient society" (Government of Malaysia, 2013, p.5).

Argentina cites participatory and citizen science as integral to their region "to develop strategies to bring science closer to society" (Ministry of Science, Technology, and Innovation, Argentina, 2022, p.16). Meanwhile, Iceland places great emphasis on defining social challenges regularly (Government of Iceland, 2020, p.45). Japan's government shows its commitment to societal engagement through the Council for Science, Technology and Innovation (CSTI), which "encourages researchers who receive annual public research funds….to actively communicate with the public regarding the contents and the results of their research activities" (MEXT, 2022, p.231). The Netherlands also highlighted adhering to "the principle of co-creation, [where] science and researchers will develop new knowledge of practical relevance in cooperation with the societal partners" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.39).

Scotland also highlights the importance of diversity by taking more diverse perspectives "into account in parliamentary business and helps us to deliver services that are more inclusive and accessible" (The Scottish Parliament, 2021, p.2). The commitment to diversity and inclusion is underscored by New Zealand, which acknowledges the lack of representation "...at all levels in our research workforce [of Māori and Pacific Peoples], with women also being underrepresented in senior roles. A system that lacks diversity risks homogeneity, stifles creativity, and has a tendency toward the status quo. Poor diversity, equity and inclusion outcomes are strongly linked to the instability of RSI careers" (New Zealand Government, 2022, p.9).

Similarly, India places a strong emphasis on inclusivity, ensuring equal opportunities for "marginalised communities, differently-abled individuals including Divyangjans, ..women…and the Lesbian, Gay, Bisexual, Transgender, Queer (LGBTQ+)" (Government of India Ministry of Science and Technology, p.9). Australia ascertains that "the benefits of science can be fully realised only when society is fully engaged with science and science actively engages with society" (Australian Government, 2017, p.12).

Ireland has set up the “National Open Research Form (NORF)…to drive the national agenda for open research” (Government of Ireland, 2022, p.29). For India, the data must be “used in and generated from publicly-funded research [which] will be available to everyone under FAIR (findable, accessible, interoperable, and reusable terms)” (Government of India Ministry of Science and Technology, 2020, p.2). This is also highlighted in Argentina’s and Australia’s documents.

Subcode: 1.1.5 Media

Netherlands, China and India specifically mentioned the role of Media in PES. According to the strategy of the Netherlands, significant attention has been given to public confidence in science and appropriate incentives by the press (Netherlands’ Ministry of Education, Culture, and Science, 2014, p.30). Likewise, the Ministry of Science and Technology of the People’s Republic of China (2022, p.3) expressed its desire for institutions and organisations in the press, publishing, radio, film, television, and culture to leverage their strengths to ensure the success of popularising science and technology.

Japan’s document includes references to video sites of individual organisations for public engagement (MEXT, 2022). Similarly, China highlights the importance of utilising entertainment platforms such as television, community radio, and comics to bring science to a wider audience (Ministry of Science and Technology of the People's Republic of China, 2022, p.5). India also acknowledges the lack of online and multimedia platforms for reciprocal engagement between scientists and society, which creates a barrier to equitable and inclusive access to science (Government of India Ministry of Science and Technology, 2020, p.43).

Main category 1.2 Types of stakeholders

Subcode: 1.2.1 Government

Since all the documents are government-written, the government plays a crucial role and is a significant stakeholder in them.

All the countries acknowledged the involvement of various stakeholders, including government departments, in their science strategies, emphasising their role in overseeing and providing assistance in implementation.

Scotland emphasises “supporting citizen participation in the work of the parliament (particularly through parliamentary committees” (The Scottish Parliament, 2021, p.1). Iceland is also involved in drafting policy to “continue on the dissemination of science and technology…” (Government of Iceland, 2020, p.46). Similarly, Japan’s “government, universities, public research institutions, and science museums will play central roles in developing co-creation platforms and promoting efforts to ensure the public nature of research” (MEXT, 2022, p.32).

All the documents emphasise the dissemination of science and technology.

Subcode: 1.2.2 Civil society

All the documents emphasised the importance of collaboration, public engagement, and the inclusion of civil society in shaping science and technology policies while also reflecting each country's unique challenges and approaches.

Countries highlighted that “cooperation is essential both within the scientific field itself and between science and private sector organisations and civil society” (Netherlands’ Ministry of Education, Culture, and Science, 2014, p.17). Similarly, Argentina’s document aimed to “foster collaborative research between academic researchers and community members” (Ministry of Science, Technology, and Innovation, Argentina, 2022, p.16).

India acknowledged that there are still “communication gaps between scientists and society, which hamper citizens' participation in scientific endeavours” (Government of India Ministry of Science and Technology, 2020, p.43). Challenges associated with civil society include the level of “trust in science debates [that] have taught us that closer contact between the scientific field and society is essential” (Netherlands’ Ministry of Education, Culture, and Science, 2014, p. 9).

China’s Law emphasises the importance of science and technology being accessible and understandable to citizens (Ministry of Science and Technology of the People’s Republic of China, 2022, p.1). Furthermore, India also recognised the need for research to address a variety of solutions for different regions and socio-economic strata, with a particular focus on rural issues (Government of India Ministry of Science and Technology, 2020, p.26).

Besides the relevant topics, Malaysia highlighted that a “linear and top-down approach is no longer relevant since it does not have the participation of consumers, customers and citizens, which is a new component of the Quadruple Helix”[9] (Government of Malaysia, 2013, p.17). Despite the willingness to engage society, Zambia’s policy stated that “despite these developments over the years, appreciation of science, technology and innovation among members of the public and policy makers remains very low” (Republic of Zambia, 2020, p.10).

Subcode: 1.2.3 Industry

The documents highlight several instances of cooperation and collaboration between stakeholders and industry. The Netherlands considered cooperation “essential both within the scientific field itself and

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[9] “The Quadruple Helix represents a shift towards systemic, open and user-centric innovation policy. Therefore, a linear and top-down approach is no longer relevant since it does not have the participation of consumers, customers and citizens which is a new component of the Quadruple Helix approach” (Government of Malaysia, 2013, p.17).

between science and private sector organisations and civil society" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.17).

Similarly, India stated that "team science collaboration will be facilitated between industry and academia, with shared financial resources, and risks and benefits" (Government of India Ministry of Science and Technology, 2020, p. 25). This is echoed in Ireland's document – "Industry-academic collaboration and research commercialisation will be cultivated..." (Government of Ireland, 2022, p.39).

South Africa's white paper was approved by the cabinet based on "consultation with a wide range of role players such as relevant government departments, civil society, business and academia" (Republic of South Africa, Department of Science and Technology, p.i).

Subcode: 1.2.4 Academia

The multifaceted and dynamic role academia plays in shaping the future of knowledge, education and societal impact was described.

Institutions worldwide are reshaping the roles and responsibilities of academic professionals. Utrecht University "has introduced a 'differentiation framework' which describes various types of professorship, each of equal status but with a different emphasis in terms of activities and responsibilities" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.39).

Ireland and India underscore the need to fortify mechanisms for academic-industry collaboration and knowledge transfer - "We will continue to strengthen mechanisms for academic-industry collaboration and knowledge transfer" (Government of Ireland, 2022, p.10). Similarly, "Team science collaboration will be facilitated between industry and academia, with shared financial resources, and risks and benefits" (Government of India Ministry of Science and Technology, 2020, p.25).

Ireland sets a vision of increasing the number of researchers " …to 15 per 1,000 employed in the Labour Force from 10 to 1,000 currently, and fully embracing lifelong learning" (Government of Ireland, 2022, p.39), and "…to pursue disciplinary and transdisciplinary research" (Government of Ireland, 2022, p.42).

India envisions establishing "Higher Education Research Centres (HERC) and Collaborative Research Centres (CRC)…to provide research inputs to policymakers and bring together stakeholders" (Government of India Ministry of Science and Technology, 2020, p.3).

Australia and New Zealand emphasised the support of diverse career paths within academia and "recognising the value of experience gained outside a particular sector – for e.g. recognising industry or entrepreneurial experience in academia"(Australian Government, 2017, p.24). While New Zealand wants "to enable people to move in and out of other sectors while maintaining their links to the traditional Research, Science and Innovation (RSI) strategy" (New Zealand Government, 2022, p.27).

Japan emphasised the crucial role of addressing research misconduct "to respond to society's trust in STI and increase STI's driving force" (MEXT, 2022, p.238).

Subcode: 1.2.5 Local authorities

Local authorities in science engagement and communication were highlighted by emphasising their importance in coordinating and delivering effective science communication activities at the community level. This is based on the respective country. In Japan, activities such as Science Agora[10] and collaborations with local authorities underscore the importance of co-creation in regional communities. The coordination efforts extend to risk communication, where government and local authorities "are collaboratively promoting risk communication activities for food safety" (MEXT, 2022, p.234).

Subcode: 1.2.6 Schools

While not all the documents specifically mentioned schools as stakeholders, those that do emphasise the pivotal role in fostering a connection between research and education, ensuring quality experiences for students, and promoting PES.

Iceland underscored the importance of supporting teachers and professionals in applying "scientific methodology to enhance the understanding of science among children and youths of the value of science" (Government of Iceland, 2020, p.34). On the other hand, Australia identified potential challenges between "capability gaps and mismatches between the skills taught in schools, the vocational education and training (VET) system and universities and those demanded by industries" (Australian Government, 2017, p. 11), that may hold back Australia.

Japan mentioned initiatives such as introducing the "fun, depth, and width of science through books" (MEXT, 2022, p.231) and sending them to schools and public libraries nationwide.

Subcode: 1.2.7 Science centres & museums

The documents indicated that science museums assist in building bridges between various stakeholders in science communication. India intends to establish science media centres acting "as an interface between media persons, scientists and science communicators that can enable mainstream media to increase its coverage of scientific topics" (Government of India Ministry of Science and Technology, 2020, p.46). However, not all the documents mention specifically the role of science centres and museums in PES. Similarly, Malaysia indicated its willingness to "expand and empower science centres to popularise and sensitise STI in society" (Government of Malaysia, 2013, p.18).

Japan noted that it has various museums specialised in various topics such as science and innovation "to promote interactive communication between researchers and the general public through its exhibitions

[10] Science Agora is an open forum in Japan that promotes collaboration and co-creation in regional communities through supporting dialogue and activities by local authorities.

and events" (MEXT, 2022, p.232). Another museum "holds exhibitions that provide opportunities to expand people's interest in nature and science across generations…" (MEXT, 2022, p.232).

Subcode: 1.2.8 NGOs

India specifically mentioned NGOs as being " involved through popular science programmes and citizen science projects at local and regional levels" (Government of India Ministry of Science and Technology, 2020, p.5).

3.2 Theme 2: Education and training

Table 3.3 gives an overview of all the main categories and sub-codes for education and training.

Table 3.3:

Main categories and sub-codes of Theme 2

Theme 2: Education and training		
Main categories	**Sub-codes**	**Description**
2.1 Formal education	2.1.1 Science education	Science education aims to provide a well-rounded understanding of various science subjects, develop critical thinking, and include practical skills.
2.2 Informal education	2.2.1 Dissemination	Refers to knowledge disseminated to publics as findings. Publics use the information, are aware and can learn.
	2.2.2 Dialogue	Refers to applications and implications of knowledge through questioning opinion and discussion.
	2.2.3 Participation	Refers to processes of interpreting and re-constructing knowledge through sharing, creating, enjoyment and critique.
2.3 Training in PES	2.3.1 Skills	Training that aims to impart practical skills and prepare individuals to engage publics with science.

Main category 2.1 Formal education

Education is a broader process that aims to provide individuals with a well-rounded understanding of concepts and theories in science. Its primary goal is to develop critical thinking, problem-solving skills, and a deeper understanding of the world through science education.

Sub-code: 2.1.1 Science education

All the documents emphasised the role of science in compulsory education, stating that "knowledge must be shared with students by means of good education" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.9), except for Scotland's document. According to the Government of Iceland (2020), the country has placed a paramount focus on the quality of education, ensuring universal access to it and continuously evolving it in tandem with societal and future needs. This is also reiterated by Argentina (Ministry of Science, Technology, and Innovation, Argentina, 2022, p.8).

Icelandic students have demonstrated poor performance in international tests such as PISA, particularly those whose first language is not Icelandic. Additionally, a growing gap has been observed between the skills of individuals in the labour market and the skills that companies are seeking. The report emphasises the need for the education system to address these challenges (Government of Iceland, 2020, p.25)

India infused its own culture such that "a new culture of Atmanirbharta (self-reliance) that includes Atmavishwas (self-confidence), Atmasamman (self-respect) and Atmachintan (self-assessment) must be inculcated among students at all educational levels" (Government of India Ministry of Science and Technology, 2020, p.15). It could be that this is a form of nationalism as a reaction to post-colonialism. Furthermore, India stated that the need for science education and communication to work together is essential "to improve science teaching" (Government of India Ministry of Science and Technology, 2020, p.5).

Ireland stated that it is willing to "promote a consistent research student experience" (Government of Ireland, 2022, p.10). Australia wants to "ensure that science education is high-quality and work-relevant at all levels of education" (Australian Government, 2017, p.12). For Ireland to achieve this, they want to ensure that "course offerings reflect latest thinking and innovation in those fields" (Government of Ireland, 2022, p.41). Furthermore, "students [should] have the opportunity to experience the world of research, [such as] accessing the latest techniques and facilities" (Government of Ireland, 2022, p.41). South Africa's "white paper supports a diversity of post-secondary education opportunities and the prioritisation of the development of technical skills for the economy, including a focus on education and training for a future of digital jobs" (Republic of South Africa, Department of Science and Technology, 2019, p.xii). Similarly, India discusses various initiatives as part of a ten-year strategy, one of which is to include "cluster school and innovation hubs in partnership with higher education institutes, private industries and local communities – for sharing resources and capacities relevant to curriculum renewal and faculty development" (Government of India Ministry of Science and Technology, 2020, p.15).

Ireland stated that to strengthen links between their R&I and teaching, they must ensure that their education system's "educators are best equipped and informed to deliver their courses" (Government of Ireland, 2022, p.41). According to the law in China, teachers are encouraged to utilise their strengths and knowledge to actively participate in and endorse initiatives that promote the accessibility of science and technology to citizens (Ministry of Science and Technology of the People's Republic of China, 2022, p.3). Malaysia aims to strengthen the education system to build its workforce by having "policies and strategies to enhance education and research for capacity building" (Government of Malaysia, 2013, p.8). Netherlands advocate that "scientific personnel should be able to pursue a full career based on excellent performance in education" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.65).

In light of digital transformation Argentina's document claimed that "in times when the digital transforms social practices, open science can contribute to make scientific knowledge more inclusive and accessible" (Ministry of Science, Technology, and Innovation, Argentina, 2022, p.10).

Main category 2.2 Informal education

Sub-code: 2.2.1 Dissemination

The role of dissemination in national documents is highlighted across various countries, emphasising the importance of sharing knowledge with citizens. The Netherlands, mentions "knowledge co-creation and knowledge circulation ('dissemination')" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.39), elucidating its emphasis on the understanding that the reciprocal exchange of knowledge is paramount in bridging the gap between the realms of academia and the wider societal fabric. Scotland underscores the significance of "events and exhibitions that inform and connect people to the Parliament" (The Scottish Parliament, 2021, p.1). Additionally, promoting parliamentary work and encouraging engagement through effective communication is deemed crucial (The Scottish Parliament, 2021, p.1).

China aims at "popularising science and technology, raising the citizens' scientific and cultural level, and promoting economic and social progress" (Ministry of Science and Technology of the People's Republic of China, 2022, p.1). PST in China focuses on adopting ways "that may make it easy for the general public to understand, accept and participate in" (Ministry of Science and Technology of the People's Republic of China, 2022, p.1). For example, efforts are being made to disseminate scientific and technological knowledge among farmers. Teachers and professionals working in PST should support these activities and make facilities like laboratories and exhibition rooms available for lectures and consultations. They should also share their expertise and take an active role in PST activities (Ministry of Science and Technology of the People's Republic of China, 2022, p.3/4)

Malaysia has adopted dissemination as a strategy to promote a culture of Science, Technology and Innovation (STI) across all levels of society. The national document emphasises the importance of instilling a culture of STI to enhance the scientific, creative and innovative thinking among Malaysians (Government of Malaysia, 2013, p.19). In this regard, Malaysia uses science centres as a means to popularise and sensitise STI in society, demonstrating a proactive approach towards utilising dissemination channels for wider societal impact (Government of Malaysia, 2013, p.20). This approach is also reflected in Zambia's policy document, which aims to "promote public awareness of science, technology, and innovation" (Republic of Zambia, 2020, p.14).

India, Australia, Iceland and Argentina all discuss dissemination of scientific knowledge to various publics. India's document makes a distinction between dissemination of knowledge as "science outreach (dissemination of scientific knowledge to non-expert audience through science popularisation activities and science journalism) and science inreach (expert to expert communication of research finding through scientific writings and deliberations" (Government of India Ministry of Science and Technology, 2020, p.43).

Australia underscores the importance of engaging the "general public [and that they] are engaged by and appreciate science, building support for investment in science" (Australian Government, 2017, p.12). Similarly, the Ministry of Science, Technology, and Innovation in Argentina (2022) has adopted a legislative approach that prioritises the dissemination of scientific knowledge generated by public funds" (Ministry of Science, Technology, and Innovation, Argentina, 2022, p.20). Conversely, South Africa highlights that caution should be practised when disseminating sensitive research and information and emphasises that public-funded research and research data may be made available to the public, after a careful analysis, with some exceptions, such as data that can compromise sovereign security and confidential information (Republic of South Africa, Department of Science and Technology, p.52).

Japan mentions several examples related to disseminating information to citizens and has agencies that "open their facilities to the public and provide lectures throughout the year, helping to raise awareness by facilitating interactive communication with the public about their research activities and by exhibiting research results" (MEXT, 2022, p.230). Furthermore, universities and public research institutions in Japan actively "make efforts to widely disseminate information on research results to the general public" (MEXT, 2022, p.231).

In South Africa, the focus is on increasing the reach of awareness and notes that science engagement activities will "increasingly target the local government level, using appropriate communication technologies and techniques, including mainstream media and social media" (Republic of South Africa, Department of Science and Technology, 2019, p.56). Similarly, New Zealand emphasises the role of the government as an enabler and investor in research dissemination "to the impact of research being publicly shared or captured by the private sector" (New Zealand Government, 2022, p.39).

Sub-code: 2.2.2 Dialogue

The role of dialogue in the national documents is pervasive and integral to these countries' goals. Whether addressing controversies, receiving public input, promoting transparency, or fostering democratic debate, the emphasis on dialogue underscores a commitment to engaging with diverse perspectives and building bridges between the scientific community and society.

The cervical cancer vaccination program in the Netherlands highlights the fact that scientific evidence alone is insufficient to ensure public acceptance. Acknowledging the controversy surrounding the program, the Netherlands' Ministry of Education, Culture, and Science emphasises that the "Trust in

Science" debates “has taught us an invaluable lesson; that closer interaction between the scientific community and society is crucial” (Netherlands’ Ministry of Education, Culture, and Science, 2014, p.9). Ireland commits to “listen to people’s concerns, for instance, about how technological developments may affect different sections of our society…championing its role [in research]…in addressing many of the issues faced by our citizens” (Government of Ireland, 2022, p.18).

India places a strong emphasis on dialogue platforms that “…would enable dialogue and knowledge transfer between researchers, science communicators and the public, raising awareness on local issues and facilitating necessary behavioural change” (Government of India Ministry of Science and Technology, 2020, p.44). It promises to dedicate a “national conference for science communication as well as…sessions within scientific conferences…to build a network of science communicators and facilitate the exchange of knowledge, skill and experience” (Government of India Ministry of Science and Technology, 2020, p.44).

Australia recognises the significance of a “scientifically engaged community [that] will value science and understand its importance to Australia’s prosperity and wellbeing, and will participate in public dialogue about science and technology” (Australian Government, 2017, p.20). Similarly, Argentina affirms that open science must “…foster open dialogue with community organisations and with indigenous peoples traditionally excluded from the production of knowledge in relation to problems that affect them and are being investigated” (Ministry of Science, Technology, and Innnovation, Argentina, 2022, p.8). Conversely, Zambia highlighted “the lack of adequate dialogue between research institutions and the intended beneficiaries hinders the dissemination of technologies” (Republic of Zambia, 2020, p.4).

Scotland emphasised the role of public dialogue as part of the democratic process (The Scottish Parliament, 2021, p.1). While Japan recognised its role in involving people in “the discussion of science and technology policies” (MEXT, 2022, p.231). South Africa also highlighted the importance of dialogue among various stakeholders including civil society in policy making (Republic of South Africa, Department of Science and Technology, 2019, p.12). This is also reiterated by Iceland’s policy stating that universities assist in serving as a “…source of knowledge-driven innovation and foster culture and democratic debate” (Government of Iceland, 2020, p.22).

Subcode: 2.2.3 Participation

While all the countries in this study mentioned the participation of stakeholders, some mentioned the specific practice of including stakeholders in the process of scientific knowledge.

The Netherlands and Ireland emphasised co-creation and collaboration between scientific entities and societal partners. The Netherlands stressed the importance of full awareness of knowledge demand “at the very beginning of the development chain, and that the potential users of that knowledge should be identified at the earliest possible opportunity” (Netherlands’ Ministry of Education, Culture, and

Science, 2014, p.9). Ireland advocated for a cultural change in research and innovation, including "increased adoption of transdisciplinary, open innovation, and participative approaches" (Government of Ireland, 2022, p.9).

Another common thread is making sure that participation is inclusive. India discusses mainstreaming science communication and public engagement, focusing on citizen-centric approaches and upstream engagement (Government of India Ministry of Science and Technology, 2020, p.5,43,44). South Africa echoes this sentiment, emphasising the engagement of all stakeholders in framing challenges and involving them from the beginning in transdisciplinary research (Republic of South Africa, Department of Science and Technology, 2019, p.19,54). New Zealand indicated the importance of public consultation by releasing a Green Paper seeking input from citizens, with over 900 submissions and significant workshop attendance (New Zealand Government, 2022, p.15).

The Scottish Parliament (2021, p.7) has emphasised the importance of involving citizens in parliamentary committees and has introduced strategies to facilitate effective public engagement, including the establishment of clear targets. To foster a culture of learning and innovation, it has been suggested that staff at all levels be encouraged to collaborate and share knowledge with both internal and external partners. Continuous feedback, evaluation, and collaborative thinking are key elements in developing and delivering excellent public engagement practices not only in the present but also in the future (The Scottish Parliament, 2021, p.7). Malaysia introduced the Quadruple Helix approach, emphasising "a shift towards systemic, open and user-centric innovation policy. Therefore, a linear and top-down approach is no longer relevant since it does not have the participation of consumers, customers and citizens, which is a new component of the Quadruple Helix approach." (Government of Malaysia, 2013, p.17)

Japan also showcases its efforts in organising forums covering various subjects to engage citizens in science-related discussions with a wide range of subjects, including industry-academia co-creation, gender equality in science, and the application of genome editing technology to human embryos (MEXT, 2022, p.233). Argentina explicitly addresses participation and citizen science challenges, such as problems in engaging individuals, tokenism, asymmetries, and ethical issues (Ministry of Science, Technology, and Innovation, Argentina, 2022, p.49). This acknowledgement of challenges reflects a commitment to addressing potential pitfalls in the participatory process.

The commitment to inclusivity, collaboration, and openness is evident across nations, reflecting a shared recognition of the importance of engaging diverse stakeholders in the scientific process.

Main category 2.3 Training in PES

Sub-code: 2.3.1 Skills

The differences in approaches among these nations highlight the varying importance placed on science communication skills within the larger context of science and research policies. While certain countries actively incorporate science communication into their training programs, others may prioritise technical expertise while still acknowledging the significance of effective science communication. These approaches showcase nations' distinct strategies to equip their researchers with the necessary skills to engage successfully with citizens and other stakeholders.

India, China, and Australia emphasised integrating science communication skills into educational curricula, recognising its significance from school level to postdoctoral research (Government of India Ministry of Science and Technology, 2020, p.16, p.44; Ministry of Science and Technology of the People’s Republic of China, 2022, p.3). Australia, in particular, underscores that "science education teaches logical thinking, quantitative analysis and problem-solving, but it also instils creativity and an open-minded approach” (Australian Government, 2017, p.19).

Ireland and the Netherlands echo this sentiment, emphasising the criticality of effective science communication for researchers to maximise their impact across academia, industry, and society (Ireland, p.10/11; Netherlands’ Ministry of Education, Culture, and Science, 2014, p.19). Ireland specifically highlights the need for researchers to possess transversal skills, including science communication, to realise their full potential (Government of Ireland, 2022, p.42).

Moreover, Argentina's focus on training in citizen science and participatory research methodologies underscores the value of science communication in engaging citizens in scientific endeavours and informing public policy development (Ministry of Science, Technology, and Innovation, Argentina, 2022, p.17).

3.3 Theme 3: Funding

Table 3.4 gives an overview of all the main categories related to funding.

Table 3.4:

Main themes and sub-codes of Theme 3

Theme 3: Funding		
Main categories	**Sub-codes**	**Description**
3.1 Source of funding	3.1.1 Government	Whether funding is given by the government towards research, development, innovation, and PES.
	3.1.2 Industry and NGOs	Whether funding is given by industries and NGOs towards research, development, innovation, and PES.
3.2 Reason for funding	3.2.1 Research	Whether funding is dedicated towards research, development, and innovation.
	3.2.2 Formal education and scholarship	Whether funding is dedicated towards formal education and scholarships to students.
	3.2.3 Outreach to society/citizens	Whether funding is dedicated towards outreach to society and citizens.

Main category 3.1 Source of funding

Sub-code: 3.1.1 Government

All countries under consideration, except for Scotland, have explicitly mentioned the allocation of governmental funding towards research and development and PE in their respective documents. Conversely, Scotland has taken a different approach, focusing more on how PE should occur rather than the allocation of funding (The Scottish Parliament, 2021). More detailed insights into funding allocation can be found in Main Category 3.2.

Sub-code: 3.1.2 Industry and NGOs

Scotland's, China's, Argentina's, and Japan's documents (MEXT, 2022) did not mention the role of funding coming from industry. Several countries emphasised the need for hybrid funding models that involve both public and private sectors. Ireland mentioned initiatives like Advanced Missions in Innovative Research Ecosystem (ADMIRE) (Government of Ireland, 2022, p.3). Similarly, India proposed the establishment of hybrid models and the creation of an STI Development Bank to facilitate investments from both sectors (Government of India Ministry of Science and Technology, 2020, p.3).

Malaysia also discussed increasing the "performance of public and private research and development funding" (Government of Malaysia, 2013, p.12).

Furthermore, incentivising private sector investment in research and development is a common strategy. South Africa discusses providing incentives such as tax breaks for industries investing in funding PhDs and technical skills development (Republic of South Africa, Department of Science and Technology, 2019, p.51). Similarly, New Zealand highlights "ensuring a clear distinction between activity taking place towards the public good, which should not attract commercial revenue, and private or industry good activity [and] which should be supported with appropriate funding from the private sector" (New Zealand Government, 2022, p.56).

Zambia, for example, emphasised the importance of partnerships between businesses, higher education institutions (HEIs), and public research institutions to improve investment and funding for science, technology, and innovation (STI) (Republic of Zambia, 2020, p.14). South Africa's white paper echoed this sentiment, emphasising the need to incentivise partnerships among businesses, HEIs, and public research institutions (Republic of South Africa, Department of Science and Technology, 2019, p.34).

Additionally, countries recognise the significant contribution of the private sector to R&D funding. Australia's national statement noted the growing investment in R&D by the private non-profit research sector, which heavily depends on philanthropic support and funding from the private sector and government (Australian Government, 2017, p.8).

Main category 3.2 Reason for funding

Sub-code: 3.2.1 Research

Funding plays a pivotal role in shaping research landscapes across the globe. The majority of the funds are spent on R&D and innovation. All the countries mentioned research as pivotal for their respective countries, except for Scotland and China – due to the nature of the documents chosen for this study (see Table 3.1).

A common element in all the countries already specified highlighted their willingness to increase public funding towards research and development. The Netherlands and South Africa emphasised collaboration between public and private sectors, aiming to leverage financial commitments for targeted research priorities (Netherlands' Ministry of Education, Culture, and Science, 2014, p.28; Republic of South Africa, Department of Science and Technology, 2019, p.vii).

There is a focus on accountability, with calls for transparency in using infrastructural funding, ensuring alignment with national priorities. Netherlands "…shall request universities and research institutes to provide accountability for their use of infrastructural funding, to follow the recommendations of the roadmap as closely as possible, and to submit regular reports" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.34). Similarly, Japan emphasised the importance of appropriately using and managing public research funds and implementing measures to prevent misuse (MEXT, 2022, p.231). New Zealand echoed this approach and wants to "improve transparency of overhead funding and expenses to address information asymmetry between researchers, institutions, and funders about the cost of research and the use of government funds" (New Zealand Government, 2022, p.57).

Additionally, measures are proposed by the Netherlands to create a level playing field for career development within the research ecosystem. Australia emphasised that funding should support basic and applied research (Netherlands' Ministry of Education, Culture, and Science, 2014, p.14). Zambia mentioned specific national priorities that research should focus on, such as "…alternative sources of energy such as solar, wind, biofuels, geothermal, nuclear and biomass" (Republic of Zambia, 2020, p.4). To reduce the cost of research funding, Zambia identified greater collaboration and "rationalisation of resources between the universities and R&D institutions" (Republic of Zambia, 2020, p.5).

Sub-code: 3.2.2 Formal education and scholarship

Funds allocated towards formal education aim to ensure a sufficient pool of skilled candidates for the future workforce. While HEIs receive funding, secondary schools are also granted funds. The role of funding in education is mentioned in official documents from countries such as the Netherlands, Ireland, India, South Africa, Australia, and New Zealand. It is worth noting that other countries may not have explicitly included funding in their education strategies as they were not the primary focus of those documents.

The Netherlands, for instance, acknowledges the challenges faced: "It is becoming increasingly difficult for university staff to strike an appropriate balance between research and education, between time in the laboratory and time in the lecture room" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.54). To address this, the government emphasised the importance of increasing investment in higher education and research related to education. Such targeted investments proposes student grants and loans system"which will be used to improve the quality of higher education, including research activities which are directly related to education" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.89).

This is echoed in India's and South Africa's documents, where India mentioned the student's role in research (Government of India Ministry of Science and Technology, 2020, p.36) and South Africa's willingness to "improve the retention of postgraduate students (Republic of South Africa, Department of Science and Technology, 2019, p.44). Similarly, New Zealand's approach is to administer the funding for tertiary education to support research-led teaching (New Zealand Government, 2022, p.64). Zambia's commitment is to "ensure that 60% of all scholarships are allocated to science, technology, and innovation" (Republic of Zambia, 2020, p.13). Australia emphasised its need to support "science and mathematics education, directly investing in Australia's future" (Australian Government, 2017, p.14).

Sub-code: 3.2.3 Outreach to society/citizens

Through this analysis, various countries (Iceland, the Netherlands, Ireland, China, India, South Africa, New Zealand, Japan, Scotland, and Argentina) prioritise funding allocations to support endeavours aimed at disseminating scientific knowledge, fostering public engagement, and enhancing the societal impact of research. Most of the documents have allocated public funds, and those benefitting from them must disseminate their research to citizens. However, they do not necessarily include them in the research process.

Although many documents discuss research funding, China's laws specifically allocate funds for PST and mandate that any property donated by public organizations or individuals for PST endeavors must be used for that purpose. It is strictly prohibited for any individual or entity to keep, withhold, or misuse these funds (Ministry of Science and Technology of the People's Republic of China, 2022, p.4). Similarly, India has dedicated "funding channels [that] will be diversified through Public-Private Partnership (PPP) models to promote science popularisation activities" (Government of India Ministry of Science and Technology, 2020, p.46).

Ireland wants to "invest in talent, and ensure that there are appropriate supports for researchers to pursue disciplinary and transdisciplinary research, engage and partner with enterprise, the public sector and civil society, be inspirational teachers and thought leaders" (Government of Ireland, 2022, p.42). The fundraising endeavours in the Netherlands aimed at bolstering scientific research have emphasised the notion that "a gift to science is a gift to society" (Netherlands' Ministry of Education, Culture, and Science, 2014, p.44). This statement reinforces the symbiotic relationship that exists between research institutions and the citizens they serve, highlighting the integral role that scientific research plays in shaping society and advancing the collective well-being of its members. Argentina specifically promotes open science, making sure that research is accessible to citizens (Ministry of Science, Technology, and Innovation, Argentina, 2022).

3.4 Conclusion

This scoping analysis of international documents aimed to highlight prevalent trends and key drivers. While somewhat tautological, it is not surprising that economic needs emerge as a significant driving force behind the pursuit of scientific excellence and the advancement of STEM fields. The emphasis on economic needs is intricately linked to the perceived significance of a strong foundation in school education. Each nation's official documents demonstrate distinct priorities and objectives in the pursuit of scientific excellence, with recurring themes encompassing the value of researchers, international collaboration, excellence, and quality assurance in advancing scientific progress. A recurrent theme across all the documents is the advocacy for the promotion of knowledge, innovation, and economic growth. However, specific economic needs, objectives, and strategies exhibit variations among countries, reflective of their unique circumstances and priorities. Informal education, predominantly through dissemination, is consistently referenced by all nations. Zambia underscores the importance of dissemination and the public's recognition of science as a valuable and essential field, a current area of deficiency. The methods of dissemination vary across the documents. Stakeholder engagement in the production of scientific knowledge is underscored by South Africa, Netherlands, Ireland, and Iceland, with dialogue identified as a mechanism to ensure democratisation. While Scotland's entire document centres on public engagement, even beyond the realm of science, it accentuates participation, in contrast to Malaysia. Nations such as Ireland and the Netherlands express a commitment to training researchers in effective communication, whereas India, China, and Australia emphasise the integration of science communication skills into educational curricula. All countries reference governmental funding for research and development, with China implementing laws that specifically allocate funds for PST. New Zealand's strategy underscores the incorporation of diverse forms of knowledge. China's dedication to popularising science and technology is reflected in its laws and dedicated resources aimed at fostering economic and social progress. This commitment is contextualised within the country's political landscape, potentially elucidating why it is enshrined in law as opposed to being articulated in a white paper or strategy.

The subsequent chapter will expand upon the quantitative data acquired from both Maltese residents and PENs.

Chapter 4

Quantitative results:

Local and international questionnaire

4.0 Introduction: Organisation of the quantitative findings

Chapter 4 is divided into two parts. The first part presents the findings from the questionnaire distributed to Maltese residents and residents who have been living in Malta for over a year. The second part of this chapter presents data and results from an international questionnaire regarding members' involvement with PENs, whether paid or otherwise. As mentioned in Chapter 2, the local questionnaire examines citizens' perceptions and their relationship of and with PES, while the international questionnaire focuses more broadly on stakeholders. A bottom-up approach was adopted, prioritising citizens as they are the key stakeholders in this project. My engagement with RRING, which concentrated on the role of networking in professional contexts, has led me to consider the importance of networking within the PSS. Currently, there are no local professional networks specifically dedicated to science communication.

Part 1: The local questionnaire

4.1 Demographics of the sample

Data was collected at events or online through social media with persons aged 18 years or older (see Table 4.1). Most of the respondents were female (284, 51.3%), while 279 respondents (48.7%) were male (see Table 4.2). The sample population was representative of the national population in terms of gender and only representative of the national population for the 25-34 and 55-64 age groups (see Table 4.4). To mitigate potential biases stemming from a non-representative dataset, data was systematically collected from a wide array of cultural, scientific, and miscellaneous events held in various geographical locations, as outlined in Section 4.1.1-4.1.3. It is essential to recognise that, at baseline, the local sample likely varied in its levels of scientific interest, influenced by the specific nature of the events (e.g., participants of Science in the City compared to those in Notte Bianca). Future research could build on this by incorporating additional correlational statistical testing to gain a deeper understanding of these differences.

Table 4.1:

Physical and online data collection of all the events

Type of data collection	Event	Frequency	Percentage
Physical	SITC	126	21.9
	Notte Bianca	38	6.6
	Birgu Fest	50	8.7
	Natalis Notabilis	48	8.3
Total Physical		262	45.6
Online	English version without Facebook ad	216	37.6
	English version with Facebook ad	68	11.8
	Maltese version without Facebook ad	19	3.3
	Maltese version with Facebook ad	10	1.7
Total Online		313	54.4
	Total Physical & online	575	100.0

Table 4.2:

Table summarising the demographic and other characteristics of the sample.

		Gender		**Age**					
Characteristic		Male	Female	18-24	25-34	35-44	45-54	55-64	65+
Demographic details		279	294	92	119	126	120	68	50
		48.7%	51.3%	16.0%	20.7%	21.9%	20.9%	11.8%	8.7%
Highest education qualification	Primary	0.6%	1.4%	0.0%	0.0%	0.0%	0.8%	1.2%	8.3%
	Secondary	9.0%	10.4%	1.8%	2.2%	6.2%	12.6%	25.9%	21.7%
	Sixth form	10.9%	11.0%	21.4%	6.6%	10.3%	9.4%	6.2%	11.7%
	Diploma	27.6%	23.1%	32.1%	18.4%	22.1%	32.3%	24.7%	20.0%
	Undergraduate degree	10.6%	14.7%	32.1%	20.6%	5.5%	4.7%	6.2%	3.3%
	Post-graduate	39.4%	38.2%	12.5%	52.2%	55.2%	38.6%	32.1%	28.3%
	Other	1.9%	1.2%	0.0%	0.0%	0.7%	1.6%	3.7%	6.7%
NGO membership	No	88.6%	88.2%	15.3%	21.5%	21.5%	20.9%	11.8%	9.0%
	Yes	11.4%	11.8%	24.2%	15.2%	25.8%	19.7%	10.6%	4.5%

4.1.1. Gender

When compared to the Malta 2019 Census results, the percentages obtained in the sample were a close representation (NSO, 2020). The sampling distribution of two population proportions was calculated to compare the weighting of the sample population and the Malta 2019 census based on gender and age. [11]

[11] More information about the sampling distribution of two population proportions can be found in Appendix 6.

Table 4.3:

Respondents' gender compared to the Maltese Census 2019

	Local questionnaire	Maltese census 2019				
Gender	Frequency	Percentage	Frequency	Percentage	Z-score	P-value
Male	279	48.7	223,357	51.6	1.407	0.159
Female	294	51.3	209,259	48.4	1.407	0.158
Total	573	100.0	432,616	100.0		

4.1.2 Age

The difference between the two proportions is not significant in all age groups except for the 25-34 and 55-64 age groups (see Table 4.4). This indicates that the sample population is not representative in these age groups and can indicate lack of attendance in social events/lack of interest in filling in the questionnaire.

Table 4.4:

Respondents' Age compared to the Maltese 2019 census data

	Local questionnaire		Maltese census 2019			
Age	Frequency	Percentage	Frequency	Percentage	Z-score	P-value
18-24	92	16.0	42,136	9.7	5.058	<0.001
25-34	119	20.7	92,933	21.6	0.536	0.589
35-44	126	21.9	79,959	18.6	2.040	0.041
45-54	120	20.9	60,567	14.1	4.669	<0.001
55-64	68	11.8	61,971	14.4	1.767	0.077
65+	50	8.7	95,050	22.1	7.748	<0.001
Total	575	100.0	432,616	100.0		

4.1.3 Current hometown

Table 4.5 shows the distribution of the respondents' current hometown. Most respondents were living in the Northern Harbour district (29.1%) and the least percentage of participants were living in Gozo and Comino (3.0%). The sample population is only representative of the entire population for the Southern Harbour and South Eastern districts as the p-value is greater than 0.05.

Table 4.5:

Respondents' current hometown compared to the Maltese 2019 census data.

	Local questionnaire		Maltese 2019 census			
District	Frequency	Percentage	Frequency	Percentage	Z-score	P-value
Northern Harbour	164	29.1	145,346	33.6	2.271	p<0.05
Northern	115	20.4	72,807	16.8	2.259	p<0.05
Southern Harbour	90	16	71,594	16.5	0.378	p=0.704
Western	87	15.4	52,461	12.1	0.016	p<0.05
South Eastern	83	14.7	61,325	14.2	0.368	p=0.711
Gozo and Comino	17	3	29,083	6.7	3.516	p<0.05
Total	564	100	432,616	100		

4.1.4 Highest education qualification

Most respondents had a high level of education, with the highest percentage of the sample (39.7%) having obtained a post-graduate degree as their highest level of education and the lowest percentage representing the respondents with only a primary level of education (0.9%). The data was also compared to Esplora's 2019 report (MISCO International Ltd., 2019) (see Table 4.6). The sample population only represents the entire population for the undergraduate degree, as the p-value is greater than 0.05.

Table 4.6:

Respondents' highest education qualification compared to Esplora 2019's report

	Local questionnaire		Esplora 2019 report			
	Frequency	Percentage	Frequency	Percentage	Z-score	P-value
Primary	5	0.9	22	5.6	4.267	p<0.05
Secondary	60	10.7	156	39.1	10.376	p<0.05
Sixth Form	58	10.3	76	19	3.832	p<0.05
Diploma	152	27	51	12.8	5.356	p<0.05
Undergraduate degree	64	11.4	42	10.4	0.434	p=0.667
Post graduate degree	223	39.7	48	12.1	9.406	p<0.05
Total	562	100	400	100		

Table 4.7 indicates that the sample population does not represent the 2011 census. While this is not an updated census version, this was the only available data.

Table 4.7:

Highest education qualification compared to 2011 census data

	Local questionnaire		Census 2011			
	Frequency	Percentage	Frequency	Percentage	Z-score	P-value
Primary	5	0.9	71254	20.37	11.465	p<0.05
Secondary	60	10.7	209715	59.96	23.818	p<0.05
Sixth Form/Diploma	210	37.3	18792	5.37	33.456	p<0.05
Tertiary education	287	51.1	49995	14.29	24.844	p<0.05
Total	562	100	349756			

4.1.5 List of members in organisations

Of the 575 participants who filled in the questionnaire, only 35 are part of a science NGO, and 23 belong to non-scientific NGOs (see Table 4.8). This is quite a low number and representation of active members within these communities.

Table 4.8:

Respondents' membership in NGOs

	Frequency	Percentage
Non-science NGOs	23	39.7
Science NGOs	35	60.3
Total	58	100.0

4.1.6 Work related to scientific field

Most respondents have never worked in a science related field (n= 297, 52.2%), while those that were currently working in a science related field represented 26.5% of the sample, with 11.2% of the responses representing those that have worked but were currently not working in a science related field (see Table 4.9).

Table 4.9:

Respondents' work in relation to a scientific field

	Local questionnaire		Esplora 2019 report[12]
	Frequency	Percentage	Percentage
No, I have never worked in a science related field	297	52.2	81.0
No, I do not currently work	64	11.2	

[12] The frequency is not available in the report. The data did not specify the criteria for 'No, I do not currently work in a science related field.'

Yes, but not anymore	57	10.0	5.9
Yes, currently working	151	26.5	12.6
Total	569	100.0	

4.2 Attendance, interest and informed about science and technology

4.2.1 Attendance to science activities

The majority of the respondents never attended science activities (n = 297, 51.9%), while 262 respondents (45.8%) reported that they attended such events (see Table 4.10).

Table 4.10:

Respondents' attendance to science activities

	Frequency	Percentage
Do not know	13	2.3
No	297	51.9
Yes	262	45.8
Total	572	100.0

4.2.2 Well informed on science, technology, and innovation

Overall, participants felt well informed about science, technology, and innovation (56.3%), while 29.3% feel uninformed or extremely uninformed and 29.3% are neutral (see Table 4.11).

Table 4.11:

Respondents and how well informed they feel about science, technology, and innovation.

	Frequency	Percentage
Extremely Uninformed	11	2.0
Not informed	67	12.3
Neutral	159	29.3
Informed	264	48.6
Extremely well informed	42	7.7
Total	543	100.0

4.2.3 Interest in science

The majority of the respondents (n= 461, 80.2%) expressed interest in science, with only a small sample of 69 respondents (12.0%) stating that they are not interested in science (see Table 4.12).

Table 4.12:

Respondents' interest in science

	Frequency	Percentage
Prefer not to say	7	1.2
Missing	1	0.2
I do not know	37	6.4
No	69	12.0
Yes	461	80.2
Total	575	100.0

4.2.4 What word comes to mind when people hear the word "science"?

Participants were prompted to provide three words that come to mind when they hear the word "science". The resulting data was categorised into five distinct groups based on common themes and analysed. The groups were:

(i) **Subject Matter:** including respondents' words referring to various science disciplines such as 'physics' (n=71), 'biology' (n=61), and 'chemistry' (n=60) or subject matter such as environment, engineering, and astronomy

(ii) **Feelings:** including words referring to emotions and feelings related to science. Most of the feelings expressed were positive, such as 'interesting' (n=26), 'fun' (n=16), and 'curious' (n=15), but there were others, such as 'difficult' (n=7), and 'breakdown' (n=3) that were not so pleasant.

(iii) **Scientific Process:** included words referring to the processes of how science is conducted. The most popular word in this group was 'experiments' (n=119), followed by 'discovery' (n=41) and 'laboratory' (n=26).

(iv) **Benefits**: included words related to the benefits of science and technology such as 'future' (n=30), 'advancement' (n=17), and 'education and learning' (n=19).

(v) **Miscellaneous**: included words that did not fit within the other four categories such as 'Einstein' (n=4). (See Table 4.13).

Overall, the most popular word cited was 'experiments' (107 times), followed by 'physics' (71 times) and 'knowledge' (63 times).

Table 4.13:

Respondents' initial thoughts about science

Category	Total number of words	Percentage
Subjects	468	39.63
Feelings	120	10.16

Scientific process	404	34.21
Benefits	149	12.62
Miscellaneous	40	3.39
Total	1181	100

4.3 Demographic data versus interest in science

The Chi-square test for independence was used where there are two categorical variables such as age and interest in science, to test the null hypothesis that there is no relationship between the two variables.

H_0: There is no association between gender, age, nationality, current hometown or highest education qualification and interest in science.

H_1: There is an association between gender, age, nationality, current hometown or highest education qualification and interest in science.

The smaller the p-value, the stronger the evidence that one should reject the null hypothesis. A p-value less than 0.05 (typically ≤ 0.05) is statistically significant. It indicates strong evidence against the null hypothesis, as there is less than a 5% probability the null is correct (and the results are random).

There was no statistical difference identified between gender, nationality or current hometown, or highest education qualification (see Tables 4.14-4.16) and their interest in science as the resulting significance value was greater than 0.05 and H_0 was accepted. Therefore, this survey data identified a statistically significant link between highest education qualification and age versus interest in science.

4.3.1 Gender vs interest in science

Table 4.14:

Gender vs interest in science

Chi-squared test

			Interest in science			
			Yes	No	I do not know	Total
Gender	Male	Count	234	30	12	276
		Percentage	84.8%	10.9%	4.3%	100.0%
	Female	Count	225	39	25	289
		Percentage	77.9%	13.5%	8.7%	100.0%
Total		Count	459	69	37	565
		Percentage	81.2%	12.2%	6.5%	100.0%

$X^2(2) = 5.62$, $p = 0.06$

4.3.2 Nationality vs interest in science

Table 4.15:

Nationality vs interest in science

Chi-squared test

Nationality vs interest in science			Interest in science: Yes	No	I do not know	Total
Nationality	Maltese	Count	423	65	33	521
		Percentage	81.2%	12.5%	6.3%	100.0%
	Non-Maltese EU	Count	23	1	2	26
		Percentage	88.5%	3.8%	7.7%	100.0%
	Non-EU	Count	15	3	2	20
		Percentage	75.0%	15.0%	10.0%	100.0%
Total		Count	461	69	37	567
		Percentage	81.3%	12.2%	6.5%	100.0%

$X^2(4) = 2.368, p = 0.668$

4.3.3 Current hometown vs interest in science

Table 4.16:

Current hometown vs interest in science

Chi-squared test

			Interest in science: Yes	No	I do not know	Total
Current hometown	Southern Harbour	Count	74	8	7	89
		Percentage	83.1%	9.0%	7.9%	100.0%
	Northern Harbour	Count	134	18	9	161
		Percentage	83.2%	11.2%	5.6%	100.0%
	South Eastern	Count	61	16	6	83
		Percentage	73.5%	19.3%	7.2%	100.0%
	Western	Count	65	17	4	86
		Percentage	75.6%	19.8%	4.7%	100.0%
	Northern	Count	95	9	10	114
		Percentage	83.3%	7.9%	8.8%	100.0%
	Gozo and Comino	Count	16	0	0	16
		Percentage	100.0%	0.0%	0.0%	100.0%
Total		Count	445	68	36	549
		Percentage	81.1%	12.4%	6.6%	100.0%

$X^2(10) = 16.546, p = 0.085$

4.3.4 Age vs interest in science

All the age groups are interested in science as seen in Table 4.17, with the most interested being the youngest cohort (18-24, 87.6%) and the least interested from the (55-64, 73.1%) age group.

Table 4.17:

Age vs interest in science

Chi-squared test

			Interest in Science			
			Yes	No	I do not know	Total
Age-group	18-24	Count	78	7	4	89
		Percentage	87.6%	7.9%	4.5%	100.0%
	25-34	Count	97	18	4	119
		Percentage	81.5%	15.1%	3.4%	100.0%
	35-44	Count	102	19	3	124
		Percentage	82.3%	15.3%	2.4%	100.0%
	45-54	Count	94	12	13	119
		Percentage	79.0%	10.1%	10.9%	100.0%
	55-64	Count	49	11	7	67
		Percentage	73.1%	16.4%	10.4%	100.0%
	65+	Count	41	2	6	49
		Percentage	83.7%	4.1%	12.2%	100.0%
Total		Count	461	69	37	567
		Percentage	81.3%	12.2%	6.5%	100.0%

$X^2(10) = 21.55$, $p = 0.018$

4.3.5 Highest education qualification vs interest in science

Those respondents with a secondary level of education are the group with the least percentage (41.7%) versus their interest in science, but then the percentage is significantly higher for diploma (84.7%), undergraduate (84.1%) and post-graduate (91.8%) (see Table 4.18).

Table 4.18:

Highest education qualification vs interest in science

Chi-squared test

Highest education qualification vs interest in science			Interest in Science: Yes	No	I do not know	Total
Highest Education Qualification	Primary	Count	4	0	1	5
		Percentage	80.0%	0.0%	20.0%	100.0%
	Secondary	Count	25	25	10	60
		Percentage	41.7%	41.7%	16.7%	100.0%
	Sixth Form	Count	40	11	7	58
		Percentage	69.0%	19.0%	12.1%	100.0%
	Diploma	Count	127	13	10	150
		Percentage	84.7%	8.7%	6.7%	100.0%
	Undergraduate degree	Count	53	7	3	63
		Percentage	84.1%	11.1%	4.8%	100.0%
	Post graduate degree	Count	201	12	6	219
		Percentage	91.8%	5.5%	2.7%	100.0%
Total		Count	450	68	37	555
		Percentage	81.1%	12.3%	6.7%	100.0%

$X^2(10) = 89.186, p < 0.001$

4.3.6 Work related to science field vs interest in science.

Respondents that do not work in a science related field are still interested in science (71.0%), even though interest is science is higher for participants that work in a scientific field (99.3.%) (see Table 4.19).

Table 4.19:

Work related to science vs interest in science.

Work related to science vs interest in science		Interest in science: Yes	No	I do not know	Total
No, I have never worked in a science related field	Count	208	57	28	293
	Percentage	71.0%	19.5%	9.6%	100.0%
No, I do not currently work	Count	46	10	7	63
	Percentage	73.0%	15.9%	11.1%	100.0%
Yes, but not anymore	Count	54	1	2	57
	Percentage	94.7%	1.8%	3.5%	100.0%
Yes, currently working	Count	149	1	0	150
	Percentage	99.3%	0.7%	0.0%	100.0%
Total	Count	457	69	37	563
	Percentage	81.2%	12.3%	6.6%	100.0%

$X^2(6) = 62.890, p < 0.001$

4.4 Demographics vs attendance to activities or events related to science.

The Chi-square test for independence was used where two categorical variables such as age and attendance to science related events, to test the null hypothesis that there is no relationship between the two variables.

H_0: There is no association between gender, age, nationality, current hometown, whether they belong to an organisation, highest education qualification, and whether they attend any activities/events related to science.

H_1: There is an association between gender, age, nationality, current hometown, whether they belong to an organisation, highest education qualification, and whether they attend any activities/events related to science.

There is no statistical difference between gender (see Table 4.20), nationality (see Table 4.22) or current hometown (see Table 4.23), and their attendance to activities or events related to science as the resulting significance value was > 0.05 and H_0 was accepted. H_0 was rejected for age (see Table 4.21), highest level of education (see Table 4.24), and whether respondents are members of any organisation and their attendance to activities or events related to science, as the level of significance was < 0.05.

4.4.1 Gender vs attendance to science activities

There is no statistical significance between gender and attendance to science activities (see Table 4.20).

Table 4.20:

Gender vs attendance to science activities

			Yes	No	I do not know	Total
Gender	Male	Count	117	154	6	277
		Percentage	42.2%	55.6%	2.2%	100.0%
	Female	Count	143	143	7	293
		Percentage	48.8%	48.8%	2.4%	100.0%
Total		Count	260	297	13	570
		Percentage	45.6%	52.1%	2.3%	100.0%

$X^2(2) = 2.637$, $p = 0.267$

4.4.2 Age vs attendance to science activities

Table 4.21 shows that the highest percentage of the population that attended science activities were the 18-24 (65.2%) age group followed by the 25-34 (50.8%) age group. The 55-64 age group had the lowest percentage (29.4%), followed by the 65+ group (32.7%) (see Table 4.21). This indicates that younger people are more likely to attend science activities than older ones.

Table 4.21:

Age vs attendance to science activities

			Yes	No	I do not know	Total
Age	18-24	Count	60	30	2	92
		Percentage	65.2%	32.6%	2.2%	100.0%
	25-34	Count	60	55	60	118
		Percentage	50.8%	46.6%	50.8%	100.0%
	35-44	Count	58	64	58	126
		Percentage	46.0%	50.8%	46.0%	100.0%
	45-54	Count	48	69	48	119
		Percentage	40.3%	58.0%	40.3%	100.0%
	55-64	Count	20	48	20	68
		Percentage	29.4%	70.6%	29.4%	100.0%
	65+	Count	16	31	16	49
		Percentage	32.7%	63.3%	32.7%	100.0%
Total		Count	262	297	262	572
		Percentage	45.8%	51.9%	45.8%	100.0%

$X^2(10) = 31.670, p < 0.001$

4.4.3 Nationality and current hometown vs attendance to science activities

There is no statistical significance between nationality and current hometown against attendance to science activities. This finding indicates that science events are relevant to a wide spectrum of nationalities (see Tables 4.22 and 4.23). No significant difference between their current hometown and whether they attend science activities also indicates that geographical locations in Malta and Gozo do not affect the attendance of science activities.

Table 4.22:

Nationality vs attendance to science activities

			Yes	No	I do not know	Total
Nationality	Maltese	Count	240	276	10	526
		Percentage	45.6%	52.5%	1.9%	100.0%
	EU	Count	12	12	2	26
		Percentage	46.2%	46.2%	7.7%	100.0%
	Non-EU	Count	10	9	1	20
		Percentage	50.0%	45.0%	5.0%	100.0%
Total		Count	262	297	13	572
		Percentage	45.8%	51.9%	2.3%	100.0%

$X^2(4) = 4.797, p = 0.309$

Table 4.23:

Current hometown vs attendance to science activities

			Yes	No	I do not know	Total
Current hometown	Southern Harbour	Count	45	43	1	89
		Percentage	50.6%	48.3%	1.1%	100.0%
	Northern Harbour	Count	74	83	6	163
		Percentage	45.4%	50.9%	3.7%	100.0%
	South Eastern	Count	38	42	2	82
		Percentage	46.3%	51.2%	2.4%	100.0%
	Western	Count	38	48	1	87
		Percentage	43.7%	55.2%	1.1%	100.0%
	Northern	Count	46	67	2	115
		Percentage	40.0%	58.3%	1.7%	100.0%
	Gozo and Comino	Count	13	3	1	17
		Percentage	76.5%	17.6%	5.9%	100.0%
Total		Count	254	286	13	13
		Percentage	45.9%	15.7%	51.7%	2.4%

$X^2(4) = 13.468$, $p = 0.199$

4.4.4 Highest education qualification vs attendance to science activities

Respondents with an undergraduate (59.4%) and postgraduate degree (55.0%) attended science activities, with the least attendance coming from primary (20.0%) and secondary education (16.7%) (see Table 4.24). This indicates that these events (cultural and science) are reaching out to those with a higher level of education.

Table 4.24:

Highest education qualification vs attendance to science activities

			Yes	No	I do not know	Total
Highest Education Qualification	Primary	Count	1	3	1	5
		Percentage	20.0%	0.0%	20.0%	100.0%
	Secondary	Count	10	49	1	60
		Percentage	16.7%	81.7%	1.7%	100.0%
	Sixth Form	Count	25	32	1	58
		Percentage	43.1%	55.2%	1.7%	100.0%
	Diploma	Count	61	85	4	150
		Percentage	40.7%	56.7%	2.7%	100.0%
	Undergraduate degree	Count	38	25	1	64
		Percentage	59.4%	39.1%	1.6%	100.0%
	Post graduate degree	Count	122	95	5	222
		Percentage	55.0%	42.8%	2.3%	100.0%
Total		Count	257	289	13	559
		Percentage	46.0%	51.7%	2.3%	100.0%

$X^2(10) = 43.243, p < 0.001$

4.4.5 Member of any organisation vs attendance

H_O was rejected since the p-value is < 0.05 criterion. Most of the respondents who stated that they are members of any organisation attend science activities. This indicates that being a member of an organisation is already a sign of taking that extra 'step' of attending science activities (see Table 4.25).

Table 4.25:

Respondents' membership status vs attendance to science activities

			Yes	No	I do not know	Total
Member of any organisation	No	Count	201	282	12	495
		Percentage	40.6%	57.0%	2.4%	100.0%
	Yes	Count	53	13	0	66
		Percentage	80.3%	19.7%	0.0%	100.0%
Total		Count	254	295	12	561
		Percentage	45.3%	52.6%	2.1%	100.0%

$X^2(10) = 43.243, p < 0.001$

4.5 Demographics vs how well informed they feel about science, technology, and innovation.

This section is based on one item in the questionnaire which asked respondents to state how well informed they are about science using a likert scale ranging from 'extremely well informed' to ‘extremely uninformed’, with the lowest score, 1, assigned to ‘I do not know’ and the highest, 6, assigned to ‘extremely well informed.’ The Kruskal Wallis test was used to compare mean rating scores provided to a statement between several independent groups clustered by age, gender etc. The Kruskal Wallis test can be used when the normality assumption is violated. This is also used when variables are not metric such as the case with the well informed variable.

The null hypothesis specifies that the mean rating scores provided to the statements vary marginally between the groups and is accepted if the p-value exceeds 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores vary significantly between the groups and is accepted if the p-value is less than the 0.05 criterion.

H_0: median score across all categories of independent variable are equal and is accepted if $p > 0.05$
H_1: median score across all categories of independent variable are not equal and is not accepted if $p < 0.05$

4.5.1 Gender vs how well-informed respondents feel about science, technology, and innovation

There is a statistically significant difference between gender and how well-informed citizens feel about science, technology, and innovation, as the p-value is < the 0.05 criterion, with males (3.638) scoring significantly higher than females (3.318). While both genders indicated what their interest in science was, self-perception was higher for males than females (see Table 4.26).

Table 4.26:

Respondents' gender vs how well informed they feel about science, technology, and innovation.

How well informed do you feel about science, technology, and innovation?

Gender	Sample Size	Mean	Std. Deviation	p-value
Male	268	3.638	0.848	<0.001
Female	274	3.318	0.884	
Total	542	3.476	0.880	

$X^2(1) = 20.596$, $p < 0.001$

4.5.2 Age vs how well-informed respondents feel about science, technology, and innovation.

All the mean rating scores are above 3 which means that there is an overall perception that the population is well informed about science technology and innovation with the over 65 age group having the highest percentage (3.681) and the 55-64 age group having the least mean rating score (3.138) (see Table 4.27).

Table 4.27:

Respondents' age vs how well informed they feel about science, technology, and innovation.

How well informed do you feel about science, technology, and innovation?

Age	Sample Size	Mean	Std. Deviation	p-value
18-24	86	3.640	0.734	0.046
25-34	113	3.487	0.907	
35-44	118	3.449	0.883	
45-54	114	3.482	0.924	
55-64	65	3.138	1.029	
65+	47	3.681	0.556	
Total	543	3.477	0.880	

$X^2(5) = 11.261$, $p = 0.046$

4.5.3 Highest education qualification

All the mean rating scores are above 3, which means that there is an overall perception that the population is well informed about science, technology, and innovation, with the respondents having a postgraduate degree (3.618) feeling more informed than respondents only having a secondary education (3.119). This indicates that the higher the level of education, the higher the perception is about how well respondents feel towards science, technology and innovation (see Table 4.28).

Table 4.28:

Respondents' education level vs how well informed they feel about science, technology, and innovation.

How well informed do you feel about science, technology and innovation?

	Sample Size	Mean	Std. Deviation	p-value
Primary	5	3.400	0.548	0.016
Secondary	59	3.119	0.966	
Sixth Form	55	3.509	0.717	
Diploma	140	3.421	0.937	
Undergraduate degree	64	3.438	0.833	
Post graduate degree	207	3.618	0.856	
Other	12	3.500	0.798	
Total	542	3.478	0.880	

$X^2(6) = 15.663$, $p = 0.016$

4.6 Frequency of attending Science centres/museums and science festivals

The chi-squared test is used to investigate the association between two categorical variables (science festivals & museums and frequency of attendance). Table 4.29 shows that 52.2% of the respondents have stated that they have attended the national museum of natural history and Malta maritime museum (51.5%), and Malta National Aquarium (46.5%) at least once. The highest percentage of participants stated that they attend whenever they have time is for National history museum of natural history (19.2%) and Esplora (18.8%), indicating that these places are worth re-visiting. The highest percentage of participants (22.9%) who have attended the SITC festival tend to re-visit the festival every year.

Table 4.29:

Frequency of attendance of science centres/museums and science festivals.

			Frequency of attendance in 2019/2020				
			Not aware of centre/festival	Never	Once	Whenever I have time	Every year
Science centres Museums and festivals	Esplora	Count	44	210	143	108	68
		Percentage	7.7%	36.6%	25.0%	18.8%	11.9%
	Life Sciences Park	Count	96	317	84	53	20
		Percentage	16.8%	55.6%	14.7%	9.3%	3.5%
	Malta National Aquarium	Count	19	159	266	64	64
		Percentage	3.3%	27.8%	46.5%	11.2%	11.2%
	National Museum of Natural History	Count	24	100	299	110	40
		Percentage	4.2%	17.5%	52.2%	19.2%	7.0%
	Malta Maritime Museum	Count	18	163	295	71	26
		Percentage	3.1%	28.4%	51.5%	12.4%	4.5%
	Science in the city	Count	41	197	125	78	131
		Percentage	7.2%	34.4%	21.9%	13.6%	22.9%
	Science in the Citadel	Count	91	370	64	27	19
		Percentage	15.9%	64.8%	11.2%	4.7%	3.3%

$X^2(24) = 979.079, p < 0.001$

4.7 Frequency of attending NGO activities

The Chi-squared test is used to investigate the association between two categorical variables (NGO's and frequency of attendance). The null hypothesis specifies that there is no association between the categorical variable and is accepted if the p-value> 0.05 level of significance. The alternative hypothesis specifies that there is a significant association between the two categorical variables and is accepted if the p-value is < the 0.05 criterion.

Table 4.30 indicates that most of the respondents have never attended science activities held by NGOs with the largest percentage attributed to Café Scientifique Gozo (69.5%), followed by Kids Dig Science (67.5%), Malta Café Scientifique (62.8%) and CineXjenza (60.6%). These activities are all organised by the Malta Chamber of Scientists.

Table 4.30:

Frequency of attendance between October 2019 – August 2020 of NGO activities

			Frequency of attending NGO activities in 2019/2020				
			Not aware of NGO	Never	Once	Whenever I have time	Every year
Activities by NGOs	CineXjenza	Count	140	346	35	38	12
		Percentage	24.5%	60.6%	6.1%	6.7%	2.1%
	Cafe Scientifique Gozo	Count	148	397	12	9	5
		Percentage	25.9%	69.5%	2.1%	1.6%	0.9%
	Malta Cafe Scientifique	Count	144	358	34	27	7
		Percentage	25.3%	62.8%	6.0%	4.7%	1.2%
	Kids Dig Science	Count	146	385	22	9	8
		Percentage	25.6%	67.5%	3.9%	1.6%	1.4%

$X^2(12) = 51.33$, $p < 0.001$

4.8 Entities and NGO's frequency attendance score

The Cronbach's alpha[13] for the entities and NGO's frequency score was over 0.7 indicating a good internal consistency between the items and therefore a score could be created (see Table 4.31).

After testing the Cronbach's alpha for validity between the statements, the Entities/NGOs frequency attendance score was compared to demographics of gender, age, current hometown, highest education qualification (Tables 4.32 - 4.35) and whether they belong to any organisation using the one-way Anova test. This test is commonly used to test for statistical differences among the means of two or more groups. There was statistical significance between all the demographics and frequency attendance scores, except for the current hometown, as the p-value exceeded 0.05. The results of the specific frequency statements and demographics (section 4.10.1)

[13] The Cronbach's Alpha measures the internal consistency between a number of related items (statements), and ranges from 0 to 1. A Cronbach's Alpha above 0.7 indicates good internal consistency between the items; a Cronbach's Alpha between 0.5 and 0.7 indicates questionable internal consistency between the items; and a Cronbach's Alpha below 0.5 indicates unacceptable internal consistency between the items.

Table 4.31:

Cronbach's alpha for institutions and NGO's frequency attendance score

Reliability Statistics

	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Entities frequency attendance score	0.712	0.714	7
NGO's frequency attendance score	0.820	0.828	4

Table 4.32:

Entities/NGOs frequency attendance score vs gender

						95% Conf. Int. for Mean	
		Sample size	Mean	Std. Dev.	P-value	Lower Bound	Upper Bound
Entities' frequency attendance score	Male	279	2.45	0.567	0.526	2.39	2.52
	Female	294	2.48	0.573		2.42	2.55
NGO's frequency attendance score	Male	279	2.68	0.619	0.241	2.61	2.76
	Female	294	2.75	0.630		2.67	2.82

Table 4.33:

Entities/NGOs frequency attendance score vs age

		Sample size	Mean	Std. Deviation	p-value
Entitites's frequency attendance score	18-24	92	1.754	0.524	<0.001
	25-34	119	1.611	0.498	
	35-44	126	2.081	0.663	
	45-54	118	1.805	0.607	
	55-64	68	1.495	0.659	
	65+	50	1.645	0.517	
	Total	573	1.766	0.614	
NGO's frequency attendance score	18-24	92	1.003	0.529	0.011
	25-34	119	0.895	0.598	
	35-44	126	1.018	0.652	
	45-54	119	0.870	0.593	
	55-64	67	0.776	0.558	
	65+	49	0.725	0.621	
	Total	572	0.906	0.602	

Table 4.34:

Entities/NGOs frequency attendance score vs highest education qualification

		Sample size	Mean	Std. Deviation	p-value
Entities frequency attendance score	Prefer not to say	1	1.286	0.000	<0.001
	Primary	5	1.448	0.348	
	Secondary	60	1.519	0.531	
	Sixth Form	58	1.682	0.521	
	Diploma	152	1.734	0.605	
	Undergraduate degree	64	1.734	0.627	
	Post graduate degree	221	1.904	0.616	
	Other	12	1.643	0.962	
	Total	573	1.766	0.614	
NGO's frequency attendance score	Prefer not to say	1	1.000	0.000	0.006
	Primary	5	0.500	0.707	
	Secondary	59	0.729	0.573	
	Sixth Form	58	0.888	0.485	
	Diploma	151	0.851	0.587	
	Undergraduate degree	64	1.047	0.630	
	Post graduate degree	222	0.981	0.624	
	Other	12	0.563	0.466	
	Total	572	0.906	0.602	

Table 4.35:

Entities/NGOs frequency attendance score vs members in NGOs

		Sample size	Mean	Std. Deviation	p-value
Entities frequency attendance score	Prefer not to say	3	2.048	0.459	<0.001
	Missing	7	1.449	0.614	
	No	497	1.711	0.598	
	Yes	66	2.204	0.564	
	Total	573	1.766	0.614	
NGO's frequency attendance score	Prefer not to say	3	0.667	0.382	<0.001
	Missing	7	0.857	0.378	
	No	496	0.865	0.581	
	Yes	66	1.224	0.685	
	Total	572	0.906	0.602	

4.9 Preferred mode of learning from different sources and entities

The Friedman test was used to compare mean rating scores between several related items/statements when the dependent variable being measured is ordinal. This mean rating score ranges from 1-5 where 1 corresponds to strongly disagree and 5 corresponds to strongly agree. The larger the mean rating score, the higher the agreement.

The null hypothesis specifies that the mean rating scores vary marginally between the items and is accepted if the p-value exceeds the 0.05 level of significance.

The alternative hypothesis specifies that the mean rating score varies between the rating statements and is accepted if p is less than 0.05.

$p>0.05$ no significant difference.

$p<0.05$ there is a significant difference.

4.9.1 Preferred mode of learning from different sources

The mean rating score provided through internet (4.197) has the largest mean rating score indicating that it is the most popular method for learning about science, development and research followed by science events (3.861), TV (3.835), blogs (3.197), newspapers (3.117), podcasts (3.120) and Radio (2.979). These mean rating scores vary significantly since the p value is approximately 0 and is less than the 0.01 criterion (level of significance) (see Table 4.36).

Table 4.36:

Preferred mode of learning from different sources

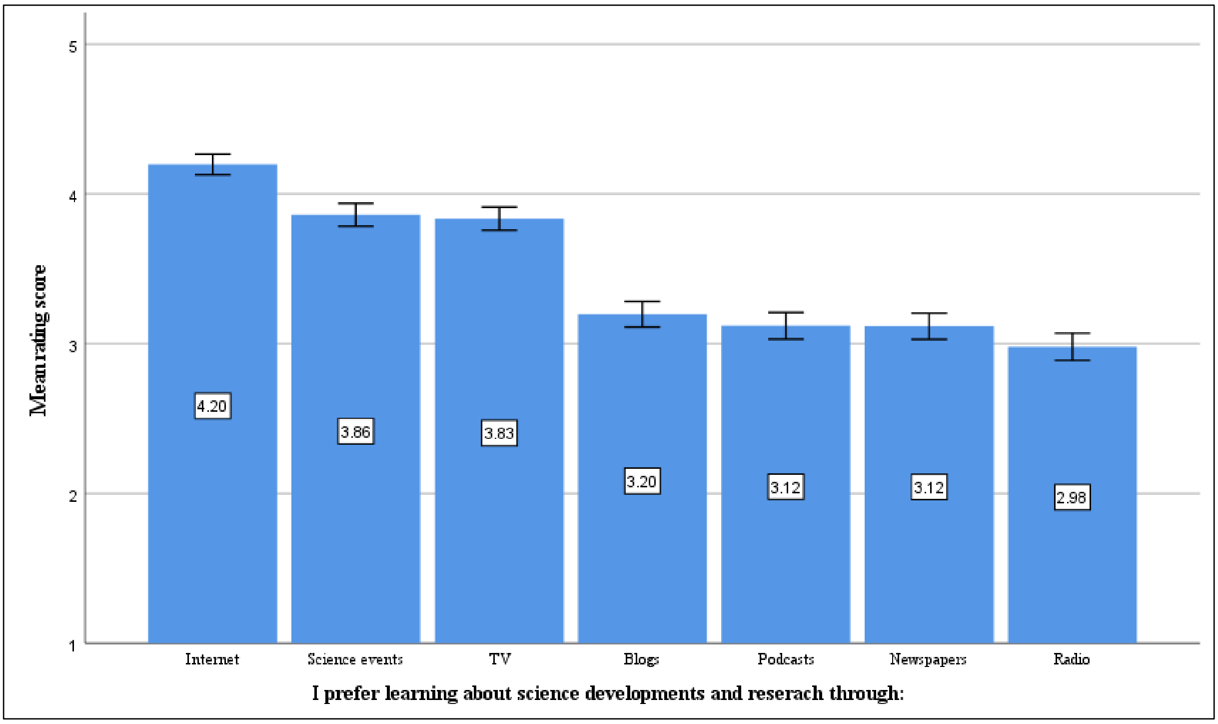
Friedman Test

Learning sources	Sample Size	Mean	Std. Deviation
Internet	575	4.197	0.840
Newspapers	575	3.117	1.065
TV	575	3.835	0.957
Radio	575	2.979	1.107
Podcasts	575	3.120	1.091
Blogs	575	3.197	1.052
Science events	575	3.861	0.927

$X^2(6) = 808.36$, $p < 0.001$

Figure 4.1:

Preferred mode of learning from different sources



Nearly all the mean rating scores are above 3 so all have a positive rating, however, there is a significant higher mean rating score for the Internet, making it the most popular medium for citizens over the age of 18 to learn about science development and research. This is followed by science events (3.86) and television (3.83), then by blogs (3.20), podcasts (3.12), and newspapers (3.12) and finally radio (2.98).

There is a significant difference as the p-value is < 0.05 criterion between Radio and Science events, TV, and the internet. There is also a statistically significant difference between podcasts and science events, TV.

The error bar graph displays the 95% confidence interval of the actual mean rating score provided to an item if the whole Maltese population aged at least 18 years was included in this study. When two confidence intervals (95%) overlap like blogs and podcasts, it indicates that their mean rating scores vary marginally. Conversely when two 95% confidence intervals are disjointed (do not overlap), this indicates that their mean rating scores vary significantly. The graph (see Figure 4.1) clearly shows that Internet is significantly more popular as a learning tool than TV and science events, which in turn are significantly more popular than newspapers, radio and podcasts and blogs. The specific distinctions between each learning source can be seen in Table 4.37.

Table 4.37:

Pairwise comparison of preferred mode of learning sources

Pairwise Comparisons

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	p-value
Radio-Podcasts	-0.221	0.127	-1.734	0.083
Radio-Newspapers	0.257	0.127	2.013	0.044

Radio-Blogs	-0.347	0.127	-2.723	0.006
Radio-Science events	-1.619	0.127	-12.709	<0.001
Radio-TV	1.626	0.127	12.763	<0.001
Radio-Internet	2.249	0.127	17.650	<0.001
Podcasts-Newspapers	0.036	0.127	0.280	0.780
Podcasts-Blogs	-0.126	0.127	-0.990	0.322
Podcasts-Science events	-1.398	0.127	-10.975	<0.001
Podcasts-TV	1.405	0.127	11.030	<0.001
Podcasts-Internet	2.028	0.127	15.916	<0.001
Newspapers-Blogs	-0.090	0.127	-0.710	0.478
Newspapers-Science events	-1.363	0.127	-10.695	<0.001
Newspapers-TV	-1.370	0.127	-10.750	<0.001
1Newspapers-Internet	1.992	0.127	15.637	<0.001
Blogs-Science events	-1.272	0.127	-9.985	<0.001
Blogs-TV	1.279	0.127	10.040	<0.001
Blogs-Internet	1.902	0.127	14.927	<0.001
Science events-TV	0.007	0.127	0.055	0.956
Science events-Internet	0.630	0.127	4.941	0.000
TV-Internet	0.623	0.127	4.887	0.000

4.9.2 Preferred mode of learning from different entities

The mean rating score provided through University of Malta (4.06) has the largest mean rating score, followed by NGOs (3.85), MCST (3.75), MCAST (3.71), Industry (3.65) with the least mean rating score for Media (3.57) and Government (3.43) (see Table 4.38).

Table 4.38:

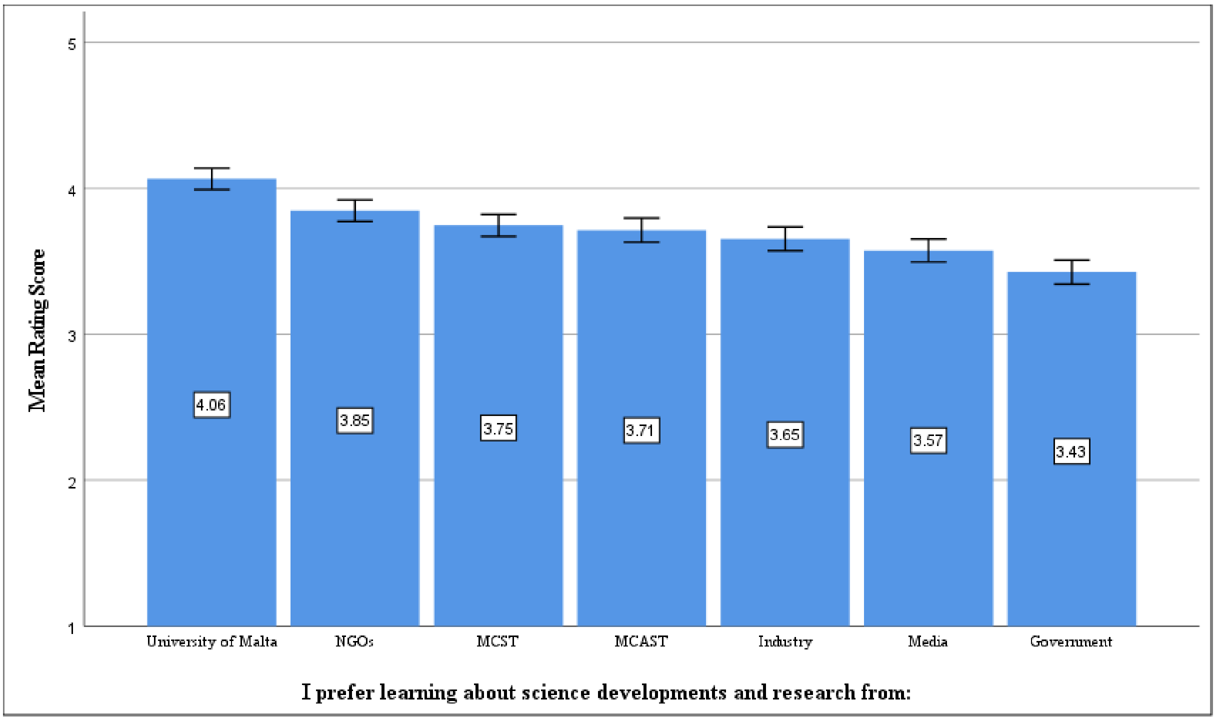
Preferred mode of learning from different entities

Friedman test

Entities	Sample size	Mean	Std. Deviation
Government	575	3.43	1.016
MCST	575	3.75	0.934
NGOs	575	3.85	0.898
Media	575	3.57	0.960
University of Malta	575	4.06	0.900
MCAST	575	3.71	1.003
Industry	575	3.65	0.981

Figure 4.2:

Preferred mode of learning from different entities



The graph (see Figure 4.2) clearly shows that University of Malta is significantly more popular as the preferred learning entity in comparison to NGOs, MCST, MCAST, industry, the media, and the government. The specific statistical difference between learning entities can be seen in Table 4.39.

Table 4.39:

Pairwise comparison of preferred mode of learning from different entities

Pairwise Comparisons

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	p-value
Government-Media	-0.316	0.127	-2.478	0.013
Government-Industry	-0.443	0.127	-3.474	0.001
Government-MCAST	-0.632	0.127	-4.962	<0.001
Government-MCST	-0.636	0.127	-4.989	<0.001
Government-NGOs	-0.836	0.127	-6.559	<0.001
Government-University of Malta	-1.387	0.127	-10.886	<0.001
Media-Industry	-0.127	0.127	-.996	0.319
Media-MCAST	-0.317	0.127	-2.484	0.013
Media-MCST	0.320	0.127	2.512	0.012
Media-NGOs	0.520	0.127	4.081	0.000
Media-University of Malta	-1.071	0.127	-8.409	0.000

Industry-MCAST	0.190	0.127	1.488	0.137
Industry-MCST	0.193	0.127	1.515	0.130
Industry-NGOs	0.393	0.127	3.085	0.002
Industry-University of Malta	0.944	0.127	7.412	0.000
MCAST-MCST	0.003	0.127	0.027	0.978
MCAST-NGOs	0.203	0.127	1.597	0.110
MCAST-University of Malta	0.755	0.127	5.924	0.000
MCST-NGOs	-0.200	0.127	-1.570	0.116
MCST-University of Malta	-0.751	0.127	-5.897	<0.001
NGOs-University of Malta	-0.551	0.127	-4.327	<0.001

4.10 Preferred learning source and entity score

A Cronbach's Alpha above 0.7 indicates that there is good internal consistency between the items and a score could be created for the above statements. Once the score was created (see Table 4.40), one-way Anova was conducted between the score and demographics: gender, age, current hometown, highest education qualification and whether they are members of an organisation. There was statistical significance between all the demographics and preferred learning source/entity scores, except for gender as the p-value exceeded 0.05 (see Table 4.41-4.13). There was also no statistical significance between preferred learning source and current hometown. Tests between demographics and specific statements about preferred learning source and entity can be found in section 4.12.

Table 4.40:

Cronbach's alpha for preferred learning source and entity

Reliability Statistics

	Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	N of Items
Preferred learning source	0.777	0.778	7
Preferred learning entity	0.712	0.714	7

Table 4.41:

Preferred learning source/entity scores vs age

		Sample size	Mean	Std. Deviation	p-value
Preferred learning source	18-24	92	2.601	0.622	0.033
	25-34	119	2.383	0.550	
	35-44	126	2.545	0.542	
	45-54	120	2.463	0.567	
	55-64	68	2.395	0.584	

	65+	50	2.389	0.526	
	Total	575	2.472	0.570	
Preferred learning entity	18-24	92	2.776	0.544	0.010
	25-34	119	2.744	0.675	
	35-44	126	2.805	0.575	
	45-54	120	2.745	0.624	
	55-64	68	2.513	0.710	
	65+	50	2.540	0.590	
	Total	575	2.718	0.626	

Table 4.42:

Preferred learning source/entity scores vs current hometown

		Sample size	Mean	Std. Deviation	p-value
Preferred learning source	Missing/Unspecified	8	2.286	0.495	0.301
	Southern Harbour	90	2.500	0.519	
	Northern Harbour	164	2.486	0.555	
	South Eastern	83	2.422	0.645	
	Western	87	2.507	0.561	
	Northern	115	2.441	0.592	
	Gozo and Comino	17	2.345	0.549	
	N/A	2	2.786	0.303	
	Other	2	3.429	0.404	
	Total	568	2.470	0.572	
Preferred learning entity	Missing/Unspecified	8	2.554	0.608	0.029
	Southern Harbour	90	2.732	0.655	
	Northern Harbour	164	2.761	0.566	
	South Eastern	83	2.837	0.676	
	Western	87	2.619	0.621	
	Northern	115	2.703	0.637	
	Gozo and Comino	17	2.269	0.604	
	N/A	2	2.571	0.808	
	Other	2	3.286	0.000	
	Total	568	2.717	0.627	

Table 4.43:

Preferred learning source/entity scores vs highest education qualification

		Sample size	Mean	Std. Deviation	p-value
Preferred learning source	Prefer not to say	1	3.429	0.000	<0.001
	Primary	5	1.829	0.519	
	Secondary	60	2.271	0.569	
	Sixth Form	58	2.456	0.529	
	Diploma	152	2.446	0.538	
	Undergraduate degree	64	2.641	0.628	

	Post graduate degree	223	2.518	0.562	
	Other	12	2.333	0.546	
	Total	575	2.472	0.570	
Preferred learning entity	Prefer not to say	1	4.000	0.000	0.010
	Primary	5	2.171	0.911	
	Secondary	60	2.576	0.603	
	Sixth Form	58	2.751	0.519	
	Diploma	152	2.659	0.656	
	Undergraduate degree	64	2.891	0.548	
	Post graduate degree	223	2.735	0.643	
	Other	12	2.881	0.434	
	Total	575	2.718	0.626	

4.11 Demographics and preferred learning source

The Kruskal Wallis test was used to compare mean rating scores provided to a statement between several independent groups in this case preferred learning sources that are clustered by age, gender etc.

The null hypothesis specified that the mean rating scores provided to the statements vary marginally between the groups and is accepted if the p-value > 0.05 level of significance. The alternative hypothesis specifies that the mean rating scores vary significantly between the groups and is accepted if the p-value < 0.05.

H_0 There is no association between gender, age, nationality, current hometown or highest education qualification and preferred learning source is accepted if p>0.05

H_1 There is an association between gender, age, nationality, current hometown or highest education qualification and preferred learning source is not accepted if p<0.05

4.11.1 Gender and preferred learning source

The mean average rating score for learning preference from different sources is either neutral or positive from all sources listed above but internet scores significantly higher as the most preferred learning source for both Males and Females. There is no gender bias discrepancy for learning preference from Internet, newspapers, TV, Radio, Podcasts and Blogs except for science events since the p-values > 0.05 (see Table 4.44). There is a statistical significance for science events as a preferred learning preference for both genders, with females scoring higher than males.

Table 4.44:

Preferred learning source and gender

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
Internet	Male	279	4.244	0.799	0.240
	Female	294	4.150	0.877	
Newspapers	Male	279	3.115	1.083	0.960
	Female	294	3.116	1.052	
TV	Male	279	3.792	0.941	0.183
	Female	294	3.871	0.972	
Radio	Male	279	2.943	1.091	0.460
	Female	294	3.007	1.124	
Podcasts	Male	279	3.151	1.099	0.461
	Female	294	3.085	1.082	
Blogs	Male	279	3.161	1.089	0.511
	Female	294	3.231	1.019	
Science events	Male	279	3.778	0.922	0.021
	Female	294	3.935	0.927	

4.11.2 Age and preferred learning source

There is an age bias discrepancy for all the learning preferences stated in this questionnaire except for the TV since the p-values are all < 0.05.

The mean average rating score for learning preference from different sources for the different age groups is either neutral or positive from all sources listed above but the internet scores significantly higher as the most preferred learning source (see Table 4.45). Internet scored significantly higher with the younger age groups (18-24, 25-35).

There is a statistical significance for science events as a preferred learning preference for all ages as the mean rating score is above 3, with the 18-24 age group scoring the most positive (4.15) and the 65+ age group with the lowest (3.56), with females scoring higher than males. Podcasts as a learning tool had a significantly higher mean rating score for the age group 18-24 (3.50) than the 55-64 age group scoring (2.90). Radio was an unpopular tool with younger age groups (18-24, 25-34, 35-44) and more popular with older age groups, mostly with the 65+ age group (3.24). Newspapers were the least popular with the 25-34 age group (2.78) and the most popular with the 65+ age group (3.34). Blogs were also more popular with younger age groups, rather than older age groups.

Table 4.45:

Preferred learning source vs age

Kruskal Wallis Test

		Sample Size	Mean	Std. Deviation	P-value
Internet	18-24	92	4.337	0.842	0.004
	25-34	119	4.361	0.767	
	35-44	126	4.190	0.777	
	45-54	120	4.158	0.799	
	55-64	68	3.956	0.984	
	65+	50	3.980	0.937	
Newspapers	18-24	92	3.109	1.114	0.004
	25-34	119	2.782	1.059	
	35-44	126	3.254	1.043	
	45-54	120	3.150	1.058	
	55-64	68	3.235	1.038	
	65+	50	3.340	0.961	
TV	18-24	92	3.663	1.122	0.129
	25-34	119	3.655	1.085	
	35-44	126	3.913	0.877	
	45-54	120	3.967	0.888	
	55-64	68	3.985	0.702	
	65+	50	3.860	0.881	
Radio	18-24	92	2.935	1.046	0.010
	25-34	119	2.672	1.082	
	35-44	126	2.968	1.088	
	45-54	120	3.150	1.207	
	55-64	68	3.103	1.095	
	65+	50	3.240	0.960	
Podcasts	18-24	92	3.500	1.084	0.002
	25-34	119	2.975	1.153	
	35-44	126	3.214	1.055	
	45-54	120	3.092	1.085	
	55-64	68	2.897	1.053	
	65+	50	2.900	0.931	
Blogs	18-24	92	3.511	0.966	<0.001
	25-34	119	3.412	1.108	
	35-44	126	3.349	0.941	
	45-54	120	2.933	1.075	
	55-64	68	2.838	1.016	
	65+	50	2.840	0.976	
Science events	18-24	92	4.152	0.925	0.001
	25-34	119	3.822	1.014	
	35-44	126	3.929	0.887	
	45-54	120	3.792	0.952	
	55-64	68	3.750	0.817	
	65+	50	3.560	0.760	

4.11.3 Current hometown and preferred learning source

There is no statistically significant difference between the source of the respondents' learning preferences and their current hometown.

4.11.4 Highest education qualification and preferred learning source

There is a significant difference of preferred learning source and highest level of education when it comes to internet, podcasts, blogs, and science events as the p-value is <0.05 and the alternative hypothesis is accepted (see Table 4.46).

Table 4.46:

Preferred learning source vs highest education qualification

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
Internet	Primary	5	3.200	1.643	<0.001
	Secondary	60	3.650	1.005	
	Sixth Form	58	4.069	0.672	
	Diploma	152	4.322	0.696	
	Undergraduate degree	64	4.344	0.859	
	Post graduate degree	223	4.269	0.827	
Newspapers	Primary	5	2.800	1.643	0.245
	Secondary	60	2.950	1.032	
	Sixth Form	58	2.931	1.041	
	Diploma	152	3.066	1.090	
	Undergraduate degree	64	3.266	1.102	
	Post graduate degree	223	3.211	1.042	
TV	Primary	5	3.200	1.095	0.300
	Secondary	60	3.833	0.717	
	Sixth Form	58	3.828	0.976	
	Diploma	152	3.914	0.898	
	Undergraduate degree	64	3.953	1.015	
	Post graduate degree	223	3.753	1.012	
Radio	Primary	5	3.200	1.095	0.673
	Secondary	60	3.033	1.119	
	Sixth Form	58	3.017	1.221	
	Diploma	152	2.849	1.114	
	Undergraduate degree	64	3.109	1.041	
	Post graduate degree	223	2.987	1.097	
Podcasts	Primary	5	2.200	0.837	0.029
	Secondary	60	2.833	1.044	
	Sixth Form	58	3.190	1.115	
	Diploma	152	3.059	1.037	
	Undergraduate degree	64	3.344	1.072	
	Post graduate degree	223	3.215	1.126	
Blogs	Primary	5	2.000	0.707	0.013
	Secondary	60	2.967	1.025	
	Sixth Form	58	3.121	1.027	
	Diploma	152	3.132	1.053	
	Undergraduate degree	64	3.391	1.093	
	Post graduate degree	223	3.300	1.033	
Science events	Primary	5	3.200	1.095	0.016
	Secondary	60	3.633	0.901	
	Sixth Form	58	4.034	0.700	
	Diploma	152	3.776	0.985	
	Undergraduate degree	64	4.078	1.044	
	Post graduate degree	223	3.888	0.901	

4.12 Interest in science and preferred learning source

The Kruskal Wallis test was conducted to identify whether there is a relationship between respondents' preferred learning source and interest in science. Only the internet and science events are statistically significant vs respondents' interest in science since the p-value is <0.05 (see Table 4.47).

Table 4.47:

Preferred learning source vs interest in science

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
Internet	Yes	461	4.286	0.789	<0.001
	No	69	3.797	0.948	
	I do not know	37	3.892	0.875	
Newspapers	Yes	461	0.000	1.075	0.209
	No	69	3.141	1.008	
	I do not know	37	2.884	1.076	
TV	Yes	461	3.189	0.988	0.957
	No	69	3.829	0.827	
	I do not know	37	3.855	0.722	
Radio	Yes	461	3.919	1.115	0.827
	No	69	2.959	1.144	
	I do not know	37	3.014	1.013	
Podcasts	Yes	461	3.027	1.101	0.059
	No	69	3.165	1.050	
	I do not know	37	2.986	1.011	
Blogs	Yes	461	2.757	1.068	0.263
	No	69	3.213	0.907	
	I do not know	37	3.174	1.140	
Science events	Yes	461	2.919	0.920	0.013
	No	69	3.915	0.988	
	I do not know	37	3.609	0.857	

4.13 Attendance to science activities, events, and preferred learning source.

There is a significant difference between attendance of science activities/events and respondents' preferred mode of learning from the Internet and science events since the p-value < 0.05, and therefore, the alternative hypothesis is accepted (see Table 4.48). The difference in learning preference between those respondents who attend science events and those who do not is significant. This suggests that there is potential for further development of science activities and events.

Table 4.48:

Preferred learning source vs attendance to science activities, events

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
Internet	Yes	262	4.298	0.790	0.002
	No	297	4.088	0.873	

	I do not know	13	4.538	0.776	
Newspapers	Yes	262	3.088	1.130	0.855
	No	297	3.135	1.004	
	I do not know	13	3.000	1.080	
TV	Yes	262	3.763	1.020	0.429
	No	297	3.896	0.885	
	Do not know	13	3.769	1.235	
Radio	Yes	262	2.973	1.139	0.557
	No	297	3.000	1.075	
	Don't know	13	2.692	1.182	
Podcasts	Yes	262	3.195	1.183	0.187
	No	297	3.044	1.001	
	I do not know	13	3.154	1.068	
Blogs	Yes	262	3.267	1.096	0.221
	No	297	3.135	1.018	
	I do not know	13	3.231	0.927	
Science events	Yes	262	4.176	0.821	<0.001
	No	297	3.616	0.916	
	I do not know	13	3.154	0.821	

4.14 Work related to science and preferred learning source.

There is a significant difference to respondents' preferred mode of learning from the Internet and science events and whether they work in a science related field as the p-value is < 0.05 criterion and therefore the alternative hypothesis is accepted. There is a significant difference between those who are working in a science related field who have shown a preference to attending science events against those who do not work in a science related field. This indicates that science events are targeting those who work in a science related field (see Table 4.49).

Table 4.49:

Preferred learning source vs work related to science and technology.

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
Internet	No, I have never worked in a science related field	297	4.088	0.873	<0.001
	No, I do not currently work	64	4.031	0.908	
	Yes, but not anymore	57	4.228	0.708	
	Yes, currently working	151	4.457	0.737	
Newspapers	No, I have never worked in a science related field	297	3.061	1.044	0.501
	No, I do not currently work	64	3.234	0.938	
	Yes, but not anymore	57	3.228	1.118	
	Yes, currently working	151	3.132	1.141	
TV	No, I have never worked in a science related field	297	3.865	0.924	0.614
	No I do not currently work	64	3.875	0.900	
	Yes, but not anymore	57	3.947	0.875	
	Yes, currently working	151	3.735	1.056	
Radio	No, I have never worked in a science related field	297	3.003	1.113	0.765
	No I do not currently work	64	2.953	1.119	
	Yes, but not anymore	57	3.035	1.085	
	Yes, currently working	151	2.921	1.111	
Podcasts	No, I have never worked in a science related field	297	3.007	1.040	0.006
	No I do not currently work	64	3.156	1.158	
	Yes, but not anymore	57	3.035	1.068	
	Yes, currently working	151	3.364	1.134	
Blogs	No, I have never worked in a science related field	297	3.104	1.020	0.075
	No I do not currently work	64	3.281	0.967	
	Yes, but not anymore	57	3.193	0.990	
	Yes, currently working	151	3.351	1.162	
Science events	No, I have never worked in a science related field	297	3.771	0.916	0.005
	No I do not currently work	64	3.813	1.052	
	Yes, but not anymore	57	3.772	1.000	
	Yes, currently working	151	4.093	0.835	

4.15 Demographics against preferred learning entity about science

4.15.1 Gender vs preferred learning entity about science

For learning preference, females are scoring significantly higher than males in government, MCST and media while males (3.56) are scoring significantly higher in Industry. Learning about science is preferred by males than females through industry sources. There is no gender bias discrepancy for learning preferences through UM, NGOs and MCAST since the p-values exceed the 0.05 level of significance (see Table 4.50).

Table 4.50:

Preferred mode of learning from different entities vs gender

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
Government	Male	279	3.348	0.999	0.048
	Female	294	3.497	1.028	
MCST	Male	279	3.659	0.934	0.023
	Female	294	3.820	0.926	
NGOs	Male	279	3.781	0.921	0.159
	Female	294	3.901	0.871	
Media	Male	279	3.477	0.959	0.022
	Female	294	3.660	0.953	
University of Malta	Male	279	4.050	0.908	0.779
	Female	294	4.075	0.894	
MCAST	Male	279	3.713	1.016	0.921
	Female	294	3.707	0.993	
Industry	Male	279	3.760	0.991	0.004
	Female	294	3.558	0.950	

4.15.2 Age and preferred learning entity

For learning preference, the 18-24 age group is scoring significantly higher than the other age groups when learning from NGOs and UM, while the over 45 age group prefer to learn from Media sources (they are scoring significantly higher) (see Table 4.51).

Table 4.51:

Preferred mode of learning from different entities vs age

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
Government	18-24	92	3.359	1.023	0.017
	25-34	119	3.487	1.080	
	35-44	126	3.532	0.961	
	45-54	120	3.550	0.986	
	55-64	68	3.221	1.063	
	65+	50	3.120	0.918	
MCST	18-24	92	3.848	0.901	0.087
	25-34	119	3.756	1.000	
	35-44	126	3.881	0.826	
	45-54	120	3.717	0.954	
	55-64	68	3.471	1.058	
	65+	50	3.640	0.802	
NGOs	18-24	92	4.076	0.867	0.012
	25-34	119	3.765	0.989	
	35-44	126	3.921	0.806	
	45-54	120	3.900	0.824	
	55-64	68	3.559	0.968	
	65+	50	3.700	0.909	
Media	18-24	92	3.500	1.064	0.413
	25-34	119	3.513	1.080	
	35-44	126	3.651	0.897	
	45-54	120	3.658	0.921	
	55-64	68	3.632	0.862	
	65+	50	3.380	0.805	
University of Malta	18-24	92	4.348	0.791	<0.001
	25-34	119	4.235	0.799	
	35-44	126	4.040	0.852	
	45-54	120	4.000	0.944	
	55-64	68	3.750	1.056	
	65+	50	3.780	0.887	
MCAST	18-24	92	3.620	1.128	0.426
	25-34	119	3.630	1.088	
	35-44	126	3.881	0.826	
	45-54	120	3.758	1.021	
	55-64	68	3.588	1.011	
	65+	50	3.720	0.882	
Industry	18-24	92	3.685	0.994	0.011
	25-34	119	3.824	1.055	
	35-44	126	3.730	0.898	
	45-54	120	3.633	0.943	
	55-64	68	3.368	1.064	
	65+	50	3.440	0.861	

4.15.3 Current hometown and preferred learning entity

For learning preference from different entities, there is a statistically significant difference between current hometown and MCAST and UM. The Northern Harbour district scored a higher mean rating score for UM (4.207), while the least mean rating score is that for Gozo and Comino (3.412). The South

Eastern district scored significantly higher (3.880) for MCAST with Gozo and Comino (3.176) scoring the east mean rating score for their preferred learning entity (see Table 4.52).

Table 4.52:

Preferred mode of learning from different entities vs current hometown

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
Government	Southern Harbour	90	3.478	1.041	0.205
	Northern Harbour	164	3.451	1.053	
	South Eastern	83	3.602	1.023	
	Western	87	3.253	1.059	
	Northern	115	3.417	0.917	
	Gozo and Comino	17	3.176	1.074	
MCST	Southern Harbour	90	3.744	0.955	0.131
	Northern Harbour	164	3.720	0.943	
	South Eastern	83	3.964	0.903	
	Western	87	3.655	0.938	
	Northern	115	3.748	0.926	
	Gozo and Comino	17	3.353	1.057	
NGOs	Southern Harbour	90	3.933	0.804	0.372
	Northern Harbour	164	3.860	0.857	
	South Eastern	83	3.807	0.943	
	Western	87	3.908	0.910	
	Northern	115	3.835	0.927	
	Gozo and Comino	17	3.353	1.115	
Media	Southern Harbour	90	3.567	1.039	0.534
	Northern Harbour	164	3.579	0.966	
	South Eastern	83	3.566	0.990	
	Western	87	3.540	0.925	
	Northern	115	3.661	0.847	
	Gozo and Comino	17	3.176	1.015	
University of Malta	Southern Harbour	90	4.056	0.964	0.018
	Northern Harbour	164	4.207	0.795	
	South Eastern	83	4.157	0.890	
	Western	87	3.977	0.849	
	Northern	115	3.948	0.944	
	Gozo and Comino	17	3.412	1.228	
MCAST	Southern Harbour	90	3.733	1.058	0.003
	Northern Harbour	164	3.805	0.946	
	South Eastern	83	3.880	1.017	
	Western	87	3.448	0.925	
	Northern	115	3.722	1.013	
	Gozo and Comino	17	3.176	1.074	
Industry	Southern Harbour	90	3.611	1.139	0.085
	Northern Harbour	164	3.707	0.886	
	South Eastern	83	3.880	0.916	
	Western	87	3.552	0.949	
	Northern	115	3.591	1.034	
	Gozo and Comino	17	3.235	0.831	

4.15.4 Highest education qualification and preferred learning entity

Citizens with only a primary level of education scored significantly lower in their learning preferences with the exception for learning from the media. Respondents with a diploma (3.408) scored significantly lower for media as their preferred learning source than those with a primary level of education (3.600) (see Table 4.53). There is a statistically significant difference between NGOs, Media, UM, and Industry as entities they want to learn about science from and with those individuals having only a primary level of education who scored the lowest, while those respondents possessing an undergraduate degree scoring significantly higher. Respondents with a primary level of education had lower learning preferences overall, except for learning from the media. The entities that respondents wanted to learn about science (NGO's, Media, UM, and Industry) from showed significant differences, with those with a primary level of education scoring the lowest and those with an undergraduate degree scoring the highest.

Table 4.53:

Preferred learning entity vs highest level of education

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
Government	Primary	5	3.000	1.225	0.625
	Secondary	60	3.483	0.930	
	Sixth Form	58	3.534	0.995	
	Diploma	152	3.368	1.065	
	Undergraduate degree	64	3.563	0.990	
	Post graduate degree	223	3.368	1.018	
MCST	Primary	5	3.000	1.414	0.743
	Secondary	60	3.700	0.869	
	Sixth Form	58	3.810	0.888	
	Diploma	152	3.803	0.892	
	Undergraduate degree	64	3.750	0.976	
	Post graduate degree	223	3.700	0.975	
NGOs	Primary	5	3.200	1.304	0.009
	Secondary	60	3.533	0.812	
	Sixth Form	58	3.845	0.721	
	Diploma	152	3.816	0.917	
	Undergraduate degree	64	4.031	0.942	
	Post graduate degree	223	3.910	0.916	
Media	Primary	5	3.600	0.894	0.002
	Secondary	60	3.733	0.686	
	Sixth Form	58	3.741	0.909	
	Diploma	152	3.408	0.979	
	Undergraduate degree	64	3.938	0.871	
	Post graduate degree	223	3.498	1.008	
University of Malta	Primary	5	3.200	0.837	<0.001
	Secondary	60	3.617	1.010	
	Sixth Form	58	4.172	0.752	
	Diploma	152	3.895	0.950	
	Undergraduate degree	64	4.344	0.781	
	Post graduate degree	223	4.206	0.840	

MCAST	Primary	5	3.000	1.000	0.656
	Secondary	60	3.617	0.993	
	Sixth Form	58	3.690	1.063	
	Diploma	152	3.717	0.979	
	Undergraduate degree	64	3.781	0.934	
	Post graduate degree	223	3.700	1.037	
Industry	Primary	5	3.200	0.837	0.020
	Secondary	60	3.350	1.087	
	Sixth Form	58	3.466	0.922	
	Diploma	152	3.605	0.964	
	Undergraduate degree	64	3.828	1.001	
	Post graduate degree	223	3.767	0.958	

4.15.5 Member of any organisation and preferred learning entity

Citizens belonging to an NGO have a higher mean rating score for UM as their preferred learning entity compared to those who are not members of any organisation. This is the only statistically significant difference between learning entity and belonging to an NGO (see Table 4.54).

Table 4.54:

Preferred learning entity vs member of any organisation

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
Government	Yes	66	3.258	1.127	0.134
	No	498	3.452	1.000	
MCST	Yes	66	3.818	0.875	0.679
	No	498	3.743	0.936	
NGOs	Yes	66	3.955	1.073	0.087
	No	498	3.835	0.877	
Media	Yes	66	3.470	1.056	0.405
	No	498	3.594	0.943	
University of Malta	Yes	66	4.333	0.950	0.002
	No	498	4.040	0.883	
MCAST	Yes	66	3.773	0.989	0.790
	No	498	3.707	1.010	
Industry	Yes	66	3.697	0.944	0.831
	No	498	3.653	0.992	

4.16 Conclusion of the local questionnaire

The first section of the quantitative results explored Maltese residents' perceptions and attitudes about science and technology and those living in Malta for longer than a year in 2019/2020. Some highlights from the local questionnaire include:

- Most Maltese residents (80.2%) are interested in science. This was a common feature irrespective of the respondents' age, even though there is a slight dip in the 55-64 age group.There was a slight dip in interest in the same age group in the MISCO's international Ltd (2019)'s report. Respondents from a U.S. survey shared that respondents were very interested in 'new scientific discoveries" (41%) and 'the use of new inventions and technologies' (40%) (National Science Board, 2020).

- Science activities are primarily attended by individuals with undergraduate and postgraduate degrees, while those with a secondary school education attend the least. Participants having just a primary or/and secondary education background registered the lowest attendance.

- The highest percentage of the population attending science activities came from the 18-24 (65.2%) age group followed by the 25-34 (50.8%) age group. The 55-64 age group registered the lowest percentage (29.4%), followed by the 65+ group (32.7%).

The growing popularity of "Science in the City," an annual science festival that draws significant attendance in Malta, has been documented (MISCO International Ltd., 2019). Nevertheless, a discernible disparity exists in the participation rates of citizens at science events, correlated with their educational backgrounds. The underrepresented demographic at these science activities predominantly comprises individuals with only a secondary level of education, who frequently perceive science as excessively complex and challenging to comprehend (MISCO International Ltd., 2019). Moreover, a study conducted by Jensen et al. (2021) on the European Researchers' Nights in Ireland, Malta, and the United Kingdom further corroborates this trend, highlighting that science events predominantly attract individuals with higher educational qualifications. Notably, Malta exhibited the highest proportion of attendees possessing advanced degrees in comparison to the other two countries, implying that there exists a societal perception of science as a domain that is inherently difficult or exclusively accessible to those considered cognitively gifted.

The results will be further explored in the discussion section to investigate and indicate how Malta's public engagement entities serve Maltese publics.

Part 2: The international questionnaire

The second part of this chapter explored the results obtained from the PEN (Public engagement with science networks) questionnaire. The final net sample size was 248. The majority (n = 190) of the members filled in 95% of the questionnaire, with members (n = 57) filling in 38%. This was the threshold completion. Due to the large amount of PENS, it was difficult to estimate the total number of members involved in these networks so an accurate response rate could not be determined. Even though targeted convenience sampling does not produce representative results, this kind of sampling was used to maximise coverage by the geographical location of the PEN.

The following definitions were applied to this questionnaire:

- **Network** – A national/global/European/trans-national association or organisation with a paid/unpaid membership structure who share the same vision, working towards a set of aims.

- **Public engagement with science networks** (PEN) - Associations or organisations of practitioners and/or scholars of science communication, public engagement with science working in areas related to Responsible Research and Innovation (RRI) or the Sustainable Development Goals (SDGs).

- **Members** – For the purposes of this research, members are anyone working in public engagement and involved in PENs, through a paid or unpaid membership.

4.17 Demographics of the PEN respondents

Most of the members were female (n=165, 65.5%), in the 31-40 age group (n= 79, 31.9%), and work at a research institution or conduct research at university (n=127, 53.6%), coming from North, West and Southern Europe (n=131, 53.5%) (see Table 4.55 and Table 4.56).

Table 4.55:

Members' gender, age and area of employment and years of work experience of the PEN questionnaire

		Frequency	Percentage
Gender	Male	87	34.5
	Female	165	65.5
	Total	252	100.0
Age	20-30	40	16.1
	31-40	79	31.9
	41-50	57	23.0
	51-60	52	21.0
	60+	20	8.1
	Total	248	100.0

Area of Employment	Education (not university)	14	5.9
	Media/Self-employed	23	9.7
	PR/Marketing agency	6	2.5
	Research Institution and Research at University	127	53.6
	Science Centres and Museums	30	12.7
	Business/Industry	8	3.4
	Retired	6	2.5
	NGO & NPO	12	5.1
	RFO	5	2.1
	Education University	6	2.5
	Total	237	100.0
Years of work experience	1-5	69	28.0
	6-10	43	17.5
	11-15	41	16.7
	16-20	37	15.0
	21-25	26	10.6
	26-30	14	5.7
	31+	11	4.5
	35+ and Retired	5	2.0
	Total	246	100.0

Table 4.56:

Members' country of residence and nationality of the PEN questionnaire

		Frequency	Percentage
Country of residence	Africa	12	4.8
	North America	31	12.4
	Latin America & Caribbean	21	8.4
	Asia	10	4.0
	North, West, Southern Europe	135	54.2
	East Europe[14]	22	8.8
	Oceania	18	7.2
	Total	249	100.0
Nationality	Africa	12	4.9
	North America	24	9.8
	Latin America & Caribbean	25	10.2
	Asia	12	4.9
	North, West, Southern Europe	131	53.5
	East Europe	23	9.4
	Oceania	18	7.3
	Total	245	100.0

[14] The division between Western and Eastern Europe is a historical and geopolitical construct that helps provide a framework for understanding the diverse countries and cultures within the European continent in relationship to PENs.

4.18 Members' involvement and paid membership in PENs

The first part of the questionnaire inquired about the respondents' involvement within the PEN and whether they have paid memberships in any of the PENs. This gave an indication of their level of commitment to the PEN. The PENs were classified into four categories based on their geographic location: global, transnational, European, and national PENs. This classification was based on where the PENs and their members are primarily located.

Most of the respondents are involved in and paid members of global and national PENs (see Table 4.57), with the majority involved in no more than three networks (see Table 4.59).

Table 4.57:

Members' involvement and paid membership in PENs stratified by geography

		Sample Size	Percentage
Involvement in PENs	Global	98	68.5%
	Trans-national	10	7.0%
	European Trans-national	48	33.6%
	National	131	91.6%
Paid PEN memberships	Global	98	68.1%
	Trans-national	7	4.9%
	European Trans-national	44	30.6%
	National	90	62.5%

Table 4.58 showed that the respondents tend to be involved in one or two PENs but tend to be paid in one PEN rather than two, indicating the possible issue of not having the necessary funds to pay for more than one national PEN membership. On the other hand, Table 4.59 showed that most of the respondents are involved and paid members in global and national networks. This assertion is supported by the data presented in the tables below, which indicates that one of the primary reasons individuals opt to leave a PEN is the high cost of membership (n-15, 23.4%, see Table 4.64). Additionally, Table 4.66 reveals that the most common reason for not joining other PENs (n=164) is also the expense of membership fees, with 55.6% of respondents citing it as a concern.

Table 4.58:

Frequency of members' involvement and paid membership in PENs

Frequency

	0	1	2	3	4	5
Involvement	104	57	42	30	7	6
Paid	102	81	40	16	5	2

Table 4.59:

Frequency of members' involvement and paid membership in PENs stratified by geography

Involvement Frequency

	0	1	2	3	4
Global	160	76	9	1	0
Trans-national	236	10	0	0	0
EU Trans-national	212	18	12	2	2
National	150	71	19	3	3

Paid/official members Frequency

	0	1	2	3	4
Global	162	74	9	0	1
Trans-national	238	8	0	0	0
EU Trans-national	214	22	7	3	0
National	167	69	9	1	0

(The total number varies as respondents could have been in more than one type of network)

The Chi-squared test was used to investigate the association between involvement with PENs and paid membership in PENs as they are two categorical variables. The null hypothesis specifies that there is no association between the categorical variable and is accepted if the p-value exceeds 0.05 level of significance. The alternative hypothesis specifies that there is a significant association between the two categorical variables and is accepted if the p-value is less than 0.05.[15] Fifty-six respondents (46.7%) involved with national PENs also have a paid membership in a global PEN. Ninety-three respondents (77.5%) were involved in National and paid in national PENs. Ninety-two (76.7%) respondents are involved in global PENs and have a paid membership. Those involved in global PENs are also paid in all four networks but still mostly global. This is the same for national networks (see Table 4.60).

[15] In the case of small counts, the Fischer’s exact test was used.

Table 4.60:

Crosstabs of Involvement with PENs vs Paid membership in PENs

Involvement with PENs		Paid membership in PENs: Global	Trans-national	European Trans-national	National	Total
Global	Count	92	5	21	48	94
	Percentage	76.7%	4.2%	17.5%	40.0%	78.3%
Trans-national	Count	12	5	2	2	9
	Percentage	10.0%	4.2%	1.7%	1.7%	7.5%
European Trans-national	Count	36	3	50	7	45
	Percentage	30.0%	2.5%	41.7%	5.8%	37.5%
National	Count	56	3	10	93	98
	Percentage	46.7%	2.5%	8.3%	77.5%	81.7%
Total	Count	86	6	34	76	120
	Percentage	71.7%	5.0%	28.3%	63.3%	100.0%

$X^2(9) = 162.222, p < 0.001$

4.19 Introduction to PEN

Most members were introduced to the network by a work colleague (n=76, 50.0%), followed by online (22.4%) and friends (13.8%) with the least percentage attributed towards flyers (2.0%) (see Table 4.61).

Table 4.61:

Introduction to PEN

Introduced to network: frequency	Sample Size	Percentage
Work colleague	76	50.0%
Online	34	22.4%
Friends	21	13.8%
Heard about it at a conference	14	9.2%
University/training courses	17	11.2%
E-mail	8	5.3%
Founders	7	4.6%
Unsure	6	3.9%
Flyer	3	2.0%

4.20 Most used communications channel

The most popular communications channel among members chosen was emails (n=82, 51.2%), and the least popular was messaging applications (1.9%) (see Table 4.62).

Table 4.62:

The most used communications channel of PENs

Members' communication channels in PENs	Frequency	Percentage
E-mails	82	51.2
Meetings	17	10.6
Conferences	21	13.1
Social Media accounts	29	18.1
Mailing lists (including e-mails)	8	5.0
Messaging applications	3	1.9

4.21 Leaving PENs

The majority of those in paid PENs have never left a network (n=162, 78.4%) (see Table 4.63). The members who left networks were asked to provide the reasons for leaving the PEN (see Table 4.64). Most of the members chose expensive membership fees (n=15, 23.4%) as the reason for leaving a PEN followed by lack of useful benefits or services (21.9%) and lack of relevance of the PEN's vision to them (17.2%). The least popular reason for leaving a PEN was lack of prestige (1.6%). Other responses given by members that were not included in this list were bullying from leaders, stopping working directly on the science communication topics and leaving the country of employment.

Table 4.63:

Members' network retention in PENs

Have you ever left a network?	Frequency	Percentage
Yes	35	21.6
No	127	78.4
Total	162	100.0

Table 4.64:

Reasons for members to leave PENs

Reasons for leaving PEN	Frequency	Percentage
Expensive membership fees	15	23.4%
Lack of useful benefits or services	14	21.9%
Vision of the network was not relevant to me anymore	11	17.2%
Lack of leadership	9	14.1%
Lack of Time	6	9.4%
Ineffective management	5	7.8%
Conflict between other members	3	4.7%

Lack of prestige	1	1.6%
Total	64	100.0%

4.22 Reasons for staying in PENs for the long term.

The most popular response for members to stay in PENs for the long term was useful services (n=141, 82.9%), followed by effective leadership (54.7%) and policy impact (47.6%). Other reasons not stated in Table 4.65 include making a real difference, meaningful connections, support to deliver engagement projects, peer support and deliverables executed in a timely fashion by appropriate staffing support.

Table 4.65:

Reasons for members to stay in PENs for the long term

Reasons to stay for the long term	Frequency	Percentage
Useful services	141	82.9%
Effective leadership	93	54.7%
Policy impact	81	47.6%
Transparency of decisions	73	42.9%
Diverse members	71	41.8%
Good management	44	25.9%
Prestige	34	20.0%
Other	26	15.3%

4.23 Reasons for not joining other networks.

Members were asked to identify the reasons for not joining other PENs from the list in Table 4.66. The most popular reason was that membership fees are too high (55.6%), followed by time restraints (48.5%) and lack of information about the PEN (46.4%). The least popular reason for not joining PENs was lack of prestige (2.7%).

Table 4.66:

Members' views on what keeps them from joining other PENs

Keeps you from joining other PENs	Sample Size	Percentage
Membership fees too high	164	55.6%
I am too busy and do not have time to spare	143	48.5%
Lack of information about the network	137	46.4%
Lack of relevance	100	33.9%
Lack of useful benefits or services	77	26.1%
Lack of prestige	8	2.7%
Unsure	8	2.7%

The Chi-square test was used as the data is categorical (keeps you from joining and gender) and not a likert scale. There are larger percentages of females who highlighted that lack of information about the network and high membership fees are the main reasons for keeping them from joining other PENs (see Table 4.67). On the other hand, there are larger percentages of males, highlighting that they are too busy with no time to spare and lack relevance in keeping them from joining other PENs. These percentage differences are significant since the p-value (0.012) is less than 0.05 level of significance.

Table 4.67:

Members' reluctance to join other PENs vs Gender

Chi-square test

Keeps you from joining other PENs vs Gender		Gender: Male	Gender: Female
Lack of information about the network	Count	15	44
	Percentage	26.3%	47.3%
Membership fees too high	Count	22	50
	Percentage	38.6%	53.8%
Lack of relevance	Count	17	20
	Percentage	29.8%	21.5%
Lack of useful benefits or services	Count	15	26
	Percentage	26.3%	28.0%
Lack of prestige	Count	2	1
	Percentage	3.5%	1.1%
I am too busy and do not have time to spare	Count	41	37
	Percentage	71.9%	39.8%

X2(5) =14.612 , p = 0.012

4.24 Network and ethical practices

Most of the members are unsure (n=80, 50.6%) whether their PEN promotes ethical practices followed by those that think that the network does indeed promote good ethical practices (43.7%) (see Table 4.68). Other responses as to what encourages good ethical practices were: guidelines and policies on harassment and conference behavioural as well as privacy and data protection guidelines and training materials such as online science journalism courses.

Table 4.68:

Members' views on whether PEN promotes good ethical practices

Does the network promote good ethical practices?	Frequency	Percentage
Yes	69	43.7
No	9	5.7
Unsure	80	50.6
Total	158	100.0

4.25 Ability to contribute versus currently contributing to the PEN

The Wilcoxon Signed Rank Test was used to compare mean rating scores provided to 2 related statements (Ability to contribute, Currently contributing). These mean rating scores range from 1-7 where 1 corresponded to Never and 7 corresponded to Always. The larger the mean rating score the higher the frequency of occurrence. A 7-point Likert scale was used to provide greater sensitivity in capturing respondents' ability and current contribution to the PEN.

The null hypothesis specifies that there is no difference between the two mean rating scores and is accepted if the p-value> 0.05 level of significance. The alternative hypothesis specifies that the two mean rating scores vary significantly and is accepted if the p-value is < 0.05 criterion.

p>0.05 -> Null hypothesis is accepted and there is no statistical significance

p<0.05 -> There is a statistical significant difference

Members are scoring higher on average in their ability to contribute to the PEN compared to their current contribution to the PEN. This difference is significant in various aspects such as time, knowledge, stakeholder contacts, mentoring, and writing proposals as indicated by the p-value in Table 4.69. However, there is no significant difference in the mean rating score for financial ability and current contribution as the p-value is > 0.05. This is visually represented in Figure 4.3.

Table 4.69:

Members' ability to contribute vs current contribution to PEN

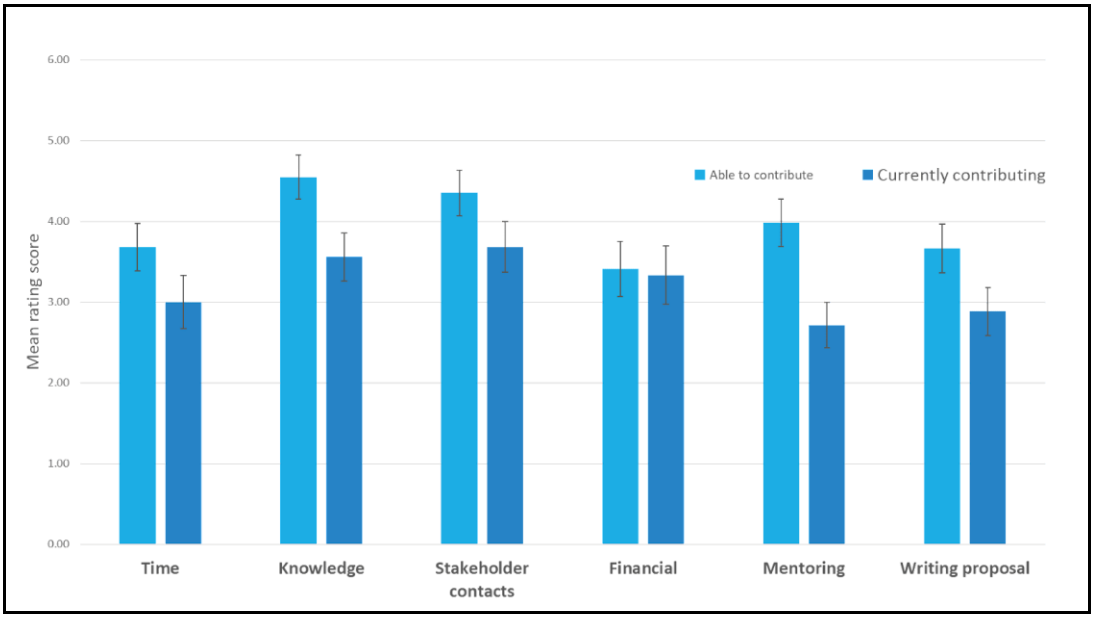
Wilcoxon Signed Rank Test

	Mean	Sample Size	Std. Deviation	p-value
Ability to Contribute - Time	3.705	176	1.895	<0.001
Currently Contributing - Time	3.017	176	2.131	
Ability to Contribute - Knowledge	4.492	185	1.736	<0.001
Currently Contributing- Knowledge	3.616	185	1.882	
Ability to Contribute Stakeholder - Contacts	4.265	181	1.858	<0.001
Currently Contributing Stakeholder - Contacts	3.696	181	2.003	
Ability to Contribute - Financial	3.429	175	2.183	0.290

Currently Contributing - Financial	3.303	175	2.316	
Ability to Contribute - Mentoring	3.994	179	1.868	<0.001
Currently Contributing - Mentoring	2.676	179	1.816	
Ability to Contribute - Writing proposals	3.619	181	1.939	<0.001
Currently Contributing - Writing proposals	2.823	181	1.950	

Figure 4.3:

Members' ability to contribute vs current contribution to PEN



4.26 Model, structure, management of networks

For the positive statements about model, structure, and management of networks (n=102), members score the highest on the statement of 'I fully support the goals of the network' (4.392), followed by 'The network's vision is clear to me' (4.137), and 'The network's leadership is effective' (3.892). In this case, the higher the mean rating score the more positive respondents feel about that particular statement. For the negative statements, members disagree that the 'Network hinders improvements' (1.618), that the 'Network's mission is difficult to relate' (1.66) and that the 'Network's objectives are difficult to understand; (1.843). In this case, the lower the mean rating score, the higher the agreement with that particular statement. Table 4.70 indicates a positive overall mean rating score on members' view about the model, structure, and management of PENs.

Table 4.70:

Members' perception about the model, structure, and management of PENs

Friedman Test

	Sample Size	Mean	Std. Deviation
The network's vision is clear to me	102	4.137	0.901
The network's leadership regularly evaluates the network's effectiveness	102	3.539	1.078
I fully support the goals of the network	102	4.392	0.706
The network's leadership is effective	102	3.892	1.004
Network's Mission Difficult to Relate (R)	102	1.657	0.906
Network's Objectives Difficult to Understand (R)	102	1.843	0.962
Network Hinders Improvements (R)	102	1.618	1.072

$X^2(6) = 359.162$, $p < 0.001$

4.26.1 Model, structure, management of networks vs demographics

The Kruskal Wallis test was used to compare mean rating scores provided to the statements related to model, structure and management of networks clustered by age, gender etc. There is no statistical significance between *gender*, *country of residence*, *nationality*, *area of employment* and statements on model, structure, and management of networks. The higher the mean rating score the more positive the respondent is towards that particular statement.

Table 4.71 shows that there was no statistical significance between statements about the model, structure and management of networks and age except for the statement, ‘I fully support the goals of the network’, with the 60 and over age group scoring a higher mean rating score (4.286) and the least mean rating score attributed to the 20-30 age group (3.909).

Table 4.71:

Members' age vs statements about model, structure, and management of PENs

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
The network's vision is clear to me	20-30	16	3.938	0.680	0.067
	31-40	37	3.838	1.093	
	41-50	35	3.971	0.891	
	51-60	29	4.414	0.628	
	60+	15	4.333	0.816	
The network's leadership regularly evaluates the network's effectiveness	20-30	14	4.068	1.027	0.233
	31-40	29	3.143	1.214	
	41-50	28	3.483	0.876	
	51-60	29	3.786	1.233	
	60+	11	3.345	0.701	
I fully support the goals of the network	20-30	17	3.909	0.707	0.014
	31-40	35	3.523	0.639	
	41-50	35	4.000	0.710	

	51-60	30	4.343	0.817	
	60+	15	4.286	0.632	
The network's leadership is effective	20-30	15	4.567	1.121	0.289
	31-40	32	4.600	1.027	
	41-50	29	4.364	0.655	
	51-60	28	3.600	1.182	
	60+	14	3.906	0.633	
Network's Mission Difficult to Relate (R)	20-30	17	4.000	0.588	0.940
	31-40	36	3.714	0.862	
	41-50	35	4.357	0.808	
	51-60	29	3.898	1.091	
	60+	14	1.706	0.975	
Network's Objectives Difficult to Understand (R)	20-30	18	1.667	0.840	0.819
	31-40	36	1.629	1.040	
	41-50	34	1.759	0.845	
	51-60	30	1.786	0.973	
	60+	14	1.695	0.914	
Network Hinders Improvements (R)	20-30	16	2.000	1.147	0.490
	31-40	35	1.944	0.914	
	41-50	35	1.794	1.211	
	51-60	30	1.867	1.070	
	60+	13	1.714	0.439	

4.27 Communication and participation between the network and its members

PENs scored well in facilitating the sharing of best practices (see Table 4.72), as members scored a high mean rating score for this positive statement (4.292). However, for the negative statements, there was a higher mean rating score (3.425) for the statement ‘Network Support Should be Greater for Skills Development’ indicating that network members require greater support in skills development. These findings highlight the areas where the PEN is performing well and where additional support may be necessary.

Table 4.72:

Members' perception about communication and participation between the PEN and its members

Friedman Test

	Sample Size	Mean	Std. Deviation
The network leadership is involved with a diverse range of stakeholders such as governments, media, citizens etc	106	3.811	1.088
The network makes me more effective in achieving public engagement-related objectives	106	3.868	0.957
The network enables sharing of best practices	106	4.292	0.743
Network Fails to Provide Professional Support (R)	106	1.953	0.930
Network Support Should be Greater for Skills Development (R)	106	3.425	0.985
Network Conferences Irrelevant to my Work (R)	106	1.708	1.069

$X^2(5) = 266.871, p < 0.001$

4.27.1 Communication and participation between the network and its members vs demographics

There is no statistical significance between *gender*, *country of residence*, *nationality*, *area of employment* and the statements about the communication and participation of network members.

There is no statistical significance between the statements in Table 4.73 and age except for the statement, 'The network makes me more effective in achieving public engagement-related objectives', with the 60 and over age group scoring a higher mean rating score (4.538) and the least mean rating score attributed to the 20-30 age group (3.500).

Table 4.73:

Communication and participation between the network and its members vs Age

Kruskal Wallis

		Sample Size	Mean	Std. Deviation	p-value
The network leadership is involved with a diverse range of stakeholders such as governments, media, citizens etc	20-30	15	3.400	1.183	0.136
	31-40	30	3.733	1.015	
	41-50	28	3.714	1.150	
	51-60	29	4.207	1.013	
	60+	12	3.833	1.115	
The network makes me more effective in achieving public engagement-related objectives	20-30	14	3.500	1.019	0.031
	31-40	34	3.735	0.963	
	41-50	33	3.879	0.740	
	51-60	30	3.833	1.085	
	60+	13	4.538	0.660	
The network enables sharing of best practices	20-30	15	4.267	0.799	0.693
	31-40	37	4.297	0.812	
	41-50	35	4.143	0.648	
	51-60	30	4.333	0.711	
	60+	14	4.071	1.269	
Network Fails to Provide Professional Support (R)	20-30	13	2.000	0.577	0.947
	31-40	36	2.111	1.008	
	41-50	33	2.000	0.901	
	51-60	30	2.067	1.048	
	60+	14	1.857	0.949	
Network Support Should be Greater for Skills Development (R)	20-30	14	3.500	0.760	0.225
	31-40	34	3.206	1.067	
	41-50	34	3.765	0.855	
	51-60	30	3.400	1.070	
	60+	12	3.333	1.073	
Network Conferences Irrelevant to my Work (R)	20-30	13	1.615	0.768	0.454
	31-40	36	2.028	1.341	

	41-50	35	1.457	0.780	
	51-60	29	1.517	0.829	
	60+	14	1.714	1.267	

4.28 Effectiveness about model structure and management of networks and effectiveness of communication and participation between the network and its members

An effectiveness score was generated for the group of statements about the model, structure, and management of PENs and the group of statements about the communication and participation between the network and its members. After reverse coding negatively worded statements, the members' effectiveness about the model structure and management of networks was generated by averaging the rating scores provided to 7 items. On the other hand, the effectiveness of communication and participation between the network and its members was generated by averaging the rating scores provided to 6 items. These mean rating scores range from 1-5 where 1 corresponds to strongly disagree and 5 to strongly agree. Hence, the larger the mean rating score the higher the effectiveness.

The Shapiro-Wilk test was used to determine whether a score distribution is normal or skewed (see Table 4.74)

The null hypothesis specifies that the score distribution is normal and is accepted if the p-value exceeds 0.05 level of significance. The alternative hypothesis specifies that the score distribution is skewed and is accepted if the p-value is less than the 0.05 criterion.

Table 4.74:

Effectiveness about model structure and management of networks and effectiveness of communication and participation between the network and its members

Tests of Normality

	Shapiro-Wilk		
	Statistic	df	P-value
Effectiveness about model, structure, and management of networks	0.940	167	<0.001
Effectiveness of communication, and participation between the network, and its members	0.980	167	0.014

The Wilcoxon Signed Ranks Test was used to compare the effectiveness between the two grouped statements as in Table 4.73. These mean rating scores range from 1-5.

The null hypothesis specifies that the two mean effectiveness scores vary marginally and is accepted if the p-value > 0.05 level of significance.

The alternative hypothesis specifies that the two mean effectiveness scores vary significantly from each other and is accepted if the p-value < the 0.05 criterion.

The mean rating score provided to the members' effectiveness score about the model, structure, and management of networks (4.04) and effectiveness of communication and participation between the network and its members (3.75) both exceed the middle score (3) (see Table 4.75). This indicates that the members' effectiveness perception is positive, however, the members are scoring significantly higher on effectiveness about model, structure and management of networks compared to the effectiveness of communication and participation between the network and its members since the p-value < 0.05 level of significance.

Table 4.75:

Members' effectiveness score between about model structure and management of networks and effectiveness of communication and participation between the network and its members

Wilcoxon Signed Ranks Test

	Mean	Sample size	Std. Deviation	P-value
Effectiveness about model, structure, and management of networks	4.04	167	0.708	<0.001
Effectiveness of communication, and participation between the network, and its members	3.75	167	0.633	

4.28.1 Relationship between members' effectiveness scores about the model, structure and management of networks and communication and participation between the network and its members

The Spearman Correlation Test (see Table 4.76) is a nonparametric test and was used to measure the strength of the relationship between the two effectiveness scores and it ranges from -1 to 1.

The null hypothesis specifies that there is no relationship between the two effectiveness scores and is accepted if the p-value >0.05 level of significance. The alternative hypothesis specifies that there is a significant relationship between the two effectiveness scores (as the correlation is significantly different from 0) and is accepted if the p-value is <0.05 level of significance.

The Spearman correlation coefficient (0.644) is positive indicating that members who are scoring high on one effectiveness score tend to score high on the other. Moreover, this possible relationship is significant as the p-value is approximately 0 and is smaller than the 0.05 level of significance.

Table 4.76:

Relationship between members' effectiveness scores about the model, structure and management of networks and communication and participation between the network and its members

Spearman Correlation

		Effectiveness of communication and participation between the network and its members
Effectiveness about model structure and management of networks	Correlation	0.644
	P-value	<0.001

4.29 Conclusion

This chapter explored the results obtained from the local and international questionnaires. Some highlights from the international quantitative questionnaire are the following:

- Members tend to contribute more to networks in terms of time, knowledge, stakeholder contacts, mentoring and writing proposals, but not financially.
- The existing financial contributions made by the members to the PEN are already at par with their financial capabilities.
- Members perceived PEN as effective in network structure, management, communication, and participation.
- Respondents tend not to join other PENs because membership fees are too high, followed by a lack of information about the network.
- The main reasons provided for staying for the long term in a PEN was useful services followed by effective leadership.

The results from this questionnaire are useful for PEN management to stay relevant to their members and for them not to opt out of their membership. The results indicate that members cannot contribute more financially, indicating a lack of funds for members working in the science communication field. Another reason could be attributed to the population's demographic, with most of the respondents being female, possibly in lower paying positions.

The following chapters will report the results obtained from the local and international interviews.

Chapter 5

Qualitative results:
Local interviews with senior management of entities conducting public engagement with science

5.0 Introduction

This chapter explores the data generated from interviews with local senior management staff from various entities that engage with PES. The following four themes were identified during the analysis, each with sub-codes that were identified through an inductive approach:

- Theme 1: Strategies, policies, and vision,
- Theme 2: Communication channels,
- Theme 3: Education and training.
- Theme 4: Personal vision for PES

Each theme will now be explored in detail.

5.1 Theme 1: Strategies, policies and vision

Table 5.1 summarises several key drivers (sub-codes) identified from the document analysis. Each will now be considered in more detail.

Table 5.1:

Main categories and sub-codes for Theme 1: Strategies, policies, and vision

Theme 1: Strategies, policies, and vision		
Main Categories	**Sub-codes**	**Description**
1.1 Entity's vision	1.1.1 MEYR	Refers to the Ministry for Education, Sport, Youth, Research, and Innovation's vision for engaging publics, specifically within the former DLAP.
	1.1.2 MCST	Refers to the Malta's Council for Science and Technology's vision for engaging publics.
	1.1.3 UM	Refers to the University of Malta's vision for engaging publics.
	1.1.4 MCAST	Refers to the Malta College of Arts, Science and Technology's vision for engaging publics.
1.2 Drivers	1.2.1 STEM uptake and STEM careers	Whether STEM (or STEAM) uptake and STEM (or STEAM) careers are national drivers.
	1.2.2 Economic needs	Whether economic needs drive the country.
	1.2.3 Scientific excellence	Whether the country emphasises the need to produce excellent research to propel the country forward and to respond to global needs.

	1.2.4 RRI and community participation within research projects	Whether the concept of responsible research and innovation and the goal of being inclusive, equitable, and seeking to involve the community within research serves as a driving force for countries.
	1.2.5 Media	Whether countries have a drive to influence the media

Main category 1.1 Entities' vision

This main category was structured according to the organised goals of the respective visions of MEYR, MCST, MCAST and UM.

Table 5.2 presents a list and frequency of stakeholders mentioned by the interviewees. Higher educational entities and political parties/government were the most frequently mentioned stakeholders. Interviewees from different organisations prioritised different stakeholders based on their roles. MEYR seemed to focus mostly on stakeholders involved directly in formal education, i.e. educators/teachers, students, and higher educational entities. Esplora and MCST expressed a wider engagement with political parties/government, higher educational entities, students, policymakers, NGOs, and media. UM, interviewees mentioned stakeholders involved in industry, higher educational entities, students, and researchers/scientists.

Table 5.2:

Frequency of stakeholders mentioned by entities

Stakeholder Code/Name	**Frequency**
Higher educational entities	163
Political parties/government	140
Researchers/Scientists	82
Students	82
Industry	56
Media	45
Educators/Teachers	39
Parents	19
NGOs	12
Policymakers	10
Local councils	3
Science communication practitioners	1

Subcode: 1.1.1 MEYR

DLAP3C explained the structure of the directorate and their role in research. While DLAP stands for Directorate for Learning and Assessment Programmes, the organisational structure has changed since the interviews were held. It is now under a new directorate called STEM and Vocational Education and Training (VET) programmes directorate. However, for this chapter and this thesis, DLAP refers to the section about STEM education within MEYR.

DLAP's "…role is to keep STEM education as a national priority…our vision is quality STEM education reaching out to all students" (DLAP1). However, it seems that Malta still needs "…to make scientific literacy a priority for the country. It is not yet a priority" (DLAP2F). DLAP's strategy involved a wide range of stakeholders, including NGOs, schools, industries, and higher education entities, depending on their expected remit in their vision of providing their students with the best educational journey. However, DLAP2F admitted, "There are very important STEM institutions on the island with whom it would have been beneficial had we engaged much more than we actually did."

DLAP strongly advocated for a comprehensive STEM education tailored to different academic achievement levels.

> We are presenting a range of (opportunities promoting STEM with all students. Because there are opportunities for whatever your level of achievement may be. Even if you do not opt for a STEM career…with some at least basics of STEM education, you are better off, which we proclaim in our processes. (DLAP1)

Providing professional support to their teachers "…is very much related to curriculum development, to resources, (and) to mentoring" (DLAP1) is their main concern. "Being an educational institution, our first communication channel is the teacher in the classroom. We train and share experiences with the teachers, expecting them to conduct the work in the classroom" (DLAP2F).

Obtaining feedback from various stakeholders is very important for DLAP as they "invest a lot in the feedback received from heads of departments and teachers so that [they] consult with them on the way forward on how to reach more people" (DLAP3C). Consultations are also conducted with school administrators (DLAP2F). DLAP wanted to reach out to as many groups as possible by targeting specific underrepresented groups – "we have targeted primary years, girls and parents. We have targeted pockets of people that literature shows that they are vulnerable in this aspect, and they need a boost" (DLAP2F). The reason for this interest lies in "that it is affecting the children now and obviously the future skilled workforce" (DLAP1).

These stakeholders were engaged through various DLAP initiatives "…to ensure that our primary and our secondary schools produce enough graduates in science subjects" (DLAP2F).

DLAP3C identified the need to manage parents' expectations and advise them of other career opportunities besides the traditional ones:

> Guidance teachers are reaching out to students, teachers, and parents so that the student can make a good decision. It is very difficult to change parents' mindset that choosing biology and chemistry meant their son or daughter would become a doctor. I am very positive that we are reaching our aim of convincing people that there are other subjects and different expectations when it comes to STEM.

DLAP1 is of the opinion that "…we need to go younger, in the early years" and organise initiatives targeting primary school science education in addition to current efforts aimed at secondary school years. DLAP also collaborated with researchers/scientists from the Faculty of Science at UM through outreach programmes like the Go4Research student internship programme (DLAP1). Moreover, DLAP extended its outreach beyond students and endeavours to promote science to a wider audience by focusing more on the area of PES.

> We also want to work on the popularisation of science for the public. We want eventually more graduates in STEM subjects, but also to pass on the message to the general public about health, environmental, climate issues, lifestyles, consumer choices and so on." (DLAP2F)

Additionally, DLAP3C affirmed that during discussions about new national policies and strategies, the common practice is for the working group to involve stakeholders who can contribute in a structured and tangible manner, particularly in providing statistics and evidence. DLAP also considers "…the actual engagement of the students in science popularisation. That is a very, very pivotal communication channel" (DLAP).

Subcode: 1.1.2 MCST

MCST is a publicly-funded entity created by the central government to provide advice on science and technology related policies. MCST4C elaborates further on MCST's remit:

> MCST is the body responsible not only for research and innovation but also for funding policy. We also administer and provide support in terms of EU funding. A big responsibility of the Council is Esplora. So MCST was involved in setting up and then running the Interactive Science Centre, which is still the only one in Malta to date.

Esplora proved to be an effective instrument in showcasing the progress made, garnering recognition from top government officials.

> We were entrusted with the running of the centre. And this has resulted in our council having an amazingly potent tool which can be used at varying levels…I can attest that our work is now being appreciated even at the highest levels of government, much more now that Esplora is up and running. (MCST1)

The science centre served as a platform to streamline complex research and innovation concepts, adapt and present them comprehensibly "…to all students, to all visitors, whether they come from a scientific background or not" (MCST4C). Maybe because Esplora "…makes things simple for people to understand…"(MCST1). "Since its opening (in 2016), there was a registered 14% increase in the perceptions of science" (MCST4C).

Collaborating with various entities allowed MCST to engage society through formal and informal means, open to other experiences, and receive feedback on their communications.

> We do not just educate, but it is a two-way process they also give us elements that are key to their own area of expertise. And the more stakeholders you work with, the more you become open minded. Sometimes you think that an idea was well communicated in a particular manner. Still, there are certain areas which would make more sense if they had to been done differently… collaboration is key. (MCST4C)

While Esplora concentrated on the physical sciences, plans to establish an extension project called Esplora Natura, focused on biological sciences and ecology, were initiated at the time of the interview (MCST4C). Esplora Natura "will have the characteristics of a museum, but it will incorporate modern (technologies)…completely interactive experience like Esplora" (MCST4C).[16]

In setting up these interactive centres, MCST held various regular stakeholder meetings (MCST) with NGOs, industry, the economic sector, and the tourism sector, especially when formulating policies (MCST4C). Nevertheless, "We do get entities, unfortunately, the governmental ones, that sometimes do not appreciate the importance of this (stakeholder engagement) …" (MCST1). However, MCST3F noted that Esplora's contribution to national STEM promotion policymaking is very small. While "Esplora engages through its social media as well, …I do not see how they engage…encourage participation in national discourse really and truly…in my opinion, we should be doing so much more" (MCST3F).

As part of its commitment to "ensuring appropriate use of funds allocated to dissemination, Esplora actively collaborates with researchers and scientists to engage stakeholders and higher educational

[16] Esplora Natura seems to have been discontinued as a project.

institutions” (MCST3F). “…we need to continue to join forces and have an excellent relationship with major institutions like MCAST and University” (MCST4C).

MCST3F lamented that although researchers are specifically funded to engage society, these funds are still controlled by Esplora. As a result:

> There is not the freedom for the researchers and the research group to enrol other people to help them engage with the wider community…Esplora reaches out to the researchers to understand their needs, views, and wants when they organise the engagement. (MCST3F)

Esplora recruits staff members with diverse backgrounds, not necessarily restricted to scientific or science engagement expertise.

> At Esplora, we employ people who have a low science background as well because I find it presumptuous to have a group of people who are highly engaged in science, and their task is to motivate people on science. What might be engaging or interesting for someone who is already conversant (with science) might not engage others. (MCST2)

Moreover, the recruiting of certain researchers seems to be influenced by efforts to promote MCST’s image.

> I think that it is influenced by government policies. I have heard it said that we want to avoid being sexist, and we need to show that this Maltese female researcher has benefitted from this European or international funding body. Look at how great Malta is and how great our research is. MCST is the catalyst for all of this. (MCST3F)

Through Esplora, MCST has partnered with various industries, including financial services, to advance the promotion of diverse STEM careers (MCST2). Esplora's mission also includes engaging with the government to ensure that the research at MCST aligns with the needs and interests of Maltese society.

> This has led to even more support from the central government and, through their technical expertise, ensuring that even the product is refined in such a way as to ensure that whatever is done at Esplora focuses on the topics of science, research, and innovation. (MCST1)

MCST4C observed that political parties and the government tend to neglect incorporating science, research, and innovation in their policies during campaigns. "I think there is consensus that research and innovation are not a sexy topic to discuss with the public because if they were, I would have put it on billboards and included it in speeches" (MCST4C).

MCST seemed to have claimed that civil society was also consulted:

> We do actually directly encourage civil society as a whole to participate in anything, from certain decisions that are taken to those that will be made regarding our next major project – Esplora Natura. So, civil society was involved, consulted, and given space to give its feedback regarding the setting up of Esplora. (MCST1)

However, MCST3F has doubts on how much civil society is truly consulted. "I see MCST more acting on a top-level approach. MCST is more interested in engaging with scientists, researchers, policy makers in government, and industry as well. Does that essentially benefit civil society?"

MCST1 is not convinced of the value of stakeholder involvement because… "it would be ridiculous to involve the stakeholders in the everyday running of an entity, as that would lead to nothing happening ever." However, at a higher level, especially in science policy, it is typically the responsibility of relevant stakeholders, including government entities, NGOs, industry, tourism, and other stakeholders, to be involved in decision-making processes.

Through its STEM Engagement Committee, Esplora "seeks to engage citizens, especially students, with STEM by teaming up with entities, like UM, MCAST and MEYR" (MCST4C). A position paper was presented at a conference that attracted more stakeholders to the Committee.

Regarding developing links to NGOs, MCST4C distinguishes between NGOs that fund research "…because that would open a niche of all the interests that could be explored" and NGOs that are crowd-pullers.

> …such as BirdLife, but also controversial entities such as Federazzjoni Kaċċaturi Nassaba Konservazzjonisti (FKNK)…these collaborations would help to unite forces and bring out the best in what people do. A Committee with different representations would help attract more people to the centre. (MCST4C)

Subcode: 1.1.3 UM

The findings showed that the UM's primary goal was to effectively engage with various stakeholders and demonstrate the efficient use of taxpayers' funds for the betterment of society. Given its status as a public-funded entity, the UM is committed to promoting research and innovation.

> I believe that the public has a right to know and to be involved to the extent that it makes sense of the research that happens on campus because it supports our salaries through taxpayers' money. Therefore, treating the public like idiots who should be insulated from what is happening up here is abusive. I see a future where probably, stakeholders may need to…at the risk of being damned forever, approve certain scientific research or not or withholding it. (UM4)

The UM engaged with various stakeholders based on the employees' job descriptions and remits. The employee's role also influenced the mode of engagement. Academics are expected to contribute in three aspects: research, teaching, and administration. "Ideally, each and every one of us does all three and dedicates approximately one-third of our time to each of the three" (UM9F). UM3 pointed out that the research conducted might not have a direct impact or output that benefits society even though it is still important for the scientific community.

> We need to be careful because people's expectations out there are that, when you are engaging in science or research or project, you are expected to end up with something which is beneficial to society. (UM3)

Certain research will receive higher priority by UM "…because it is not possible to promote or to disseminate everything. Only a good chunk of what is being achieved at the university can be disseminated" (UM3).

At UM, RRI was introduced through the NUCLEUS EU-funded project. After the project was finished, "a Committee for Research Engagement (CRE) was established to continue its work" (UM8F). CRE is also planning to engage with all the relevant stakeholders properly.

> …there are many people and stakeholders involved in CRE. It is essential that we come up with a common vision, which will then feed back into the strategies and policies that we need to enact so that we do engage properly with our stakeholders out there. (UM8F)

UM provided faculties/institutes/centres with the opportunity to submit a proposal to set up "…research clusters at university (with) funds provided by the government, that will be, sort of, administered internally by the university" (UM10C). Contrary to current practice, these research clusters aim at developing a more holistic approach to research by encouraging the formation of multidisciplinary research teams across different faculties/institutes/centres/entities. It is believed that "this leads to…higher level research, which is more applied and sustainable" (UM10C).

UM recognises the significance of students as key stakeholders. To maintain high quality standards, UM adopts a comprehensive Quality Assurance Framework incorporating external feedback from stakeholders, including students. "This process ensures that the programs meet the required standards and are aligned with the stakeholders' expectations. The exercise also helps identify improvement areas by reviewing what was successful and what was not" (UM11C).

UM3 feels that "communicating research and results helps the UM to rise in international rankings. This, in turn, entices more international students to choose to study at the UM. Currently, international students make up 10% of the entire UM student population."

According to UM9F UM's remit extends beyond producing graduates:

> As an academic society, we are also responsible for alerting people about current issues. The discussion may be more complex than it seems. Hopefully, we enable the conversations so that more options are presented…and possibly be considered by the policymakers. (UM9F)

The UM's strategic plan for 2020-2024[17] includes eight themes highlighting the importance of education and engagement with science. However, UM1 felt that there is no clear strategy in place that effectively recognised and rewarded academics' efforts in disseminating knowledge, engaging with the community, and promoting outreach. UM3 stated that civil society was consulted, and their feedback was incorporated in developing the strategy.

> …with the introduction of the strategy document that the UM has introduced, the number of workshops or events conducted with practically all the aspects of civil society hints at the importance of the university reaching out there to elicit feedback on the way forward for future years. (UM3)

UM1 pointed out that outreach activities are voluntary and are not recognised as part of an academic's obligation under the current collective agreement. Additionally, the resources needed to engage citizens and students with scientific research are inadequate.

Academics who engage in outreach on particular issues do so "because they feel committed to a particular cause, but then they end up being overworked, as they are called repeatedly, e.g., to participate in discussion programmes on the media" (UM5).

Referring to Science in the City, UM3 points out that it is a

> One national event and thousands of people flocking to the capital city to be there, is a good start. Whether the impacts trickle at the lower levels and impact youngsters remains to be seen. Current numbers hint that we are not being successful there. (UM3)

To recruit "…more graduates, more students, a tailored approach is required so that they are willing to pursue STEM projects. This kind of communication is being handled mostly at the faculty level" (UM8F).

UM3 further highlighted that there is no clear UM marketing strategy at prioritising which subjects/courses take precedence over others. What makes the situation worse "is that the lack of national funding is determining the research agenda" (UM8F).

Researchers dedicate a lot of their time to administering research funds, which leaves less time for public engagement. What is missing is a system that rewards academics or staff for disseminating their

[17] Reference is made to the following document – *Strategic Theme 3: promote public outreach*

research. Also, there is no recognition of the work done by staff who engage in science, research, and technology with different audiences.

> We have a lot on our plate; we have to teach, administrative duties, and projects to run, and it feels like chasing around the clock on a never-ending to-do list. Adding public engagement on top of that is a big extra. (UM1)

Although UM, through its faculties, is involved with various local professional bodies such as MCST and MCAST, UM3 questions “whether its involvement is now being structured within a cohesive strategy remains to be seen.”

UM3 further explained:

> Unfortunately… the strategy is too fragmented. There are too many players involved who want to have it their own way. When establishing an overarching strategy for science and technology, I think there should be fewer players and one cohesive strategy. (UM3)

UM5 has highlighted the absence of effective communication among various entities despite the abundance of PES activities:

> ... there are a lot of initiatives that are taking place, Esplora is one of them, the Ministry of Education has another initiative, … well there are so many initiatives. However, I am not sure whether they are talking to each other. (UM5)

According to UM5, the programmes on the UM’s radio station, Campus FM, are mostly “…about history, or literature, perhaps a little about well-being, but I do not think that we have a good science programme.” UM6 highlighted that to communicate scientific research effectively, “…you need people who are very conversant, not only with their subject but the way they communicate with the different strata of society.” The UM rector had appointed a delegate to coordinate science popularisation initiatives at the UM “who in turn involved a team of people” (UM7).

UM9F criticised UM’s three main faculties related to science for their lack of practice approach towards citizens with science: “There is a need to engage more regularly with stakeholders, rather than simply when a crisis emerges, or a desperate need arises for experience or there is a need for consultancy” (UM8F).

Subcode: 1.1.4 MCAST

MCAST1 recognised the significance of MCAST's promotion of science and technology courses by involving "…the various stakeholders, and we reach out to the different stakeholders. I think it is very important that we involve ourselves much more" (MCAST1). MCAST's involvement in such activities is possible because "…given that science is something that is all around us all the time, you can find different topics and different methodologies on how to involve yourselves" (MCAST1). "However, this would not be possible without the financial support from the government" (MCAST1).

MCAST coordinated school visits with MEYR to encourage young students to pursue science.

> We hold many meetings with other stakeholders like the Education Department regarding younger students. We hold regular visits for school children and teenagers and showcase our courses, and we instil in them that science is a real thing. (MCAST1)

MCAST's outreach activities involve their students, who are given opportunities to observe and participate in workshops and conferences. It also caters to students from diverse backgrounds by adopting a personalised approach to teaching and learning, including offering them various opportunities to excel.

MCAST1 specifically noted MCAST's attention to language use when communicating with different stakeholders. Citing one example:

> When we had students delivering a lecture and using the terminology and the language that farmers were using, the farmers were all engaged. It was amazing to see how the people's attention span completely changed. They started asking questions, suggesting ways on how to improve the methodology, how to improve the experimentation and offering their assistance. (MCAST1)

MCAST1 also stated that they engage with industry to keep their courses relevant for their students and to keep up-to-date with today's job market. Other stakeholders that MCAST engaged with are those working in the agriculture sector.

> It is pointless holding a series of lectures, etc., because the audience out there [referring to farmers] is very different, and the way they appreciate things and try to improve things, then you have them on board, and they are your own champions at the end of the day. (MCAST1)

Main category 1.2 Drivers

Subcode: 1.2.1 STEM Uptake and STEM careers

The promotion of STEM education and careers plays a crucial role in shaping research and innovation policies in various entities. While the Education Directorate and higher educational entities prioritise this driver, the former placed more emphasis on it due to its direct relationship with education.

> A priority for our institution is STEM uptake and STEM careers...We are trying to increase the number of students taking up STEM options at Form 3 (Year 9)[18] level so that more students opt for STEM studies at post-secondary and tertiary or beyond. (DLAP1)

This is further emphasised by DLAP2F, who also included the role of STEAM - "Several factors prioritise our policies and strategies...definitely STEM and increasingly STEAM is one of our priorities." This importance stems from a recognition of its potential to increase the STEM workforce because

> ...at the European level, 3% of the workforce is investing in digital technology in a STEM education scenario, which is expected to increase to another 2% per year. In Malta, we already have over 4%. (DLAP 3C)

Furthermore, DLAP3C highlighted the lack of awareness among Maltese parents about career prospects and that they "need to realise that traditional means of learning and choosing careers, and not solely STEM, are holding students back – so there needs to be a shift in mentality."

Apparently, the uptake in Biology and Chemistry was unaffected by the introduction of vocational subjects.

> Even though very recently we have introduced several vocational and applied subjects at the school level which gave the students a wider choice, still our statistics show that the number of students taking biology and chemistry and computing has more or less kept steady. (DLAP2F)

[18] Students are typically 12/13 years old

The active promotion of STEM and STEAM subjects at the primary and secondary levels was emphasised by UM employees as it can increase enrolment in UM's STEM/STEAM courses.

> We do give importance...to try and encourage students, who are still at their secondary level of education or even earlier, to make STEM subjects or STEAM subjects more attractive to them, to try and attract more students to innovation. (UM10C)

UM11C further emphasised this: "Science and STEM subjects are recognised as having strategic importance in Higher Education for Malta's economy, society and the environment."

UM prioritised STEM education and workfoce preparation. A former UM pro-rector claimed that UM's educational approach produced graduates with versatile knowledge and skills applicable across various professions, not limited to specific career paths.

> ...but we do not work to create careers, we are here to create graduates...I do not think there is any particular need to address, for example, mass unemployment. If anything, the area that needs addressing is how to encourage even more people to take up STEM-related courses. And that is where your popularisation of science comes in. (UM9F)

Similarly, an MCAST1 employee stressed the importance of STEM uptake and STEM careers as an essential driver – "Given that MCAST's degrees and its tuition are based more on hands-on experience, it also is tending to industry, so I would say that STEM uptake and STEM careers are the highest priority here for MCAST."

Consequently, MCAST accept school visits to attract students to their STEM courses

> We also open our doors very regularly to visits from secondary and sometimes primary school students – because we need to show them that if they choose science, there is a career you can continue to study and various opportunities. (MCAST1)

Although MCST generally does not focus on STEM uptake and STEM careers as a priority, the interactive science centre Esplora (under MCST's remit) regards this driver as a "first priority, and our second priority would be public engagement with STEM" (MCST2). MCST4C attributed the accomplishment of its objective to its structure: "We prioritise different aspects in different units. And that is the strength of MCST. We can use Esplora to bring forward projects to the public."

Subcode: 1.2.2 Economic needs

MCST and UM prioritise economic needs in the context of research policies, funding, and social applicability. MCST2 stated, "When it comes to MCST, I believe that economic needs, scientific excellence, and RRI would be the priorities."

UM staff members elaborated on the significant impact of economic factors on research efforts that promote long-term sustainable job growth. UM2 highlighted that "...one of the driving factors since we are [...] promoting people doing research here, is generating the economy through [employing people on] our various projects." UM3 expressed that the rector's slogan is "serving students, scholars, and society sustainably" while being "aware that industry has often reached out to our academics to address certain aspects in research and the projection of certain technology."

UM5 further highlighted the relevance of economic needs in terms of social applicability – "As a public university, based on taxpayer money we need to take into consideration the country's economic and social needs, and that is also why, possibly, we receive so much from society, and we need to give back."

UM10C announced that the UM is developing a cluster-based research framework that will focus on funding research projects that align with the economic requirements of Malta that:

> [...] should be taken into consideration when we produce our research and innovation policies, and in fact, we are working on a cluster concept. This will ask the government for more funds in return for research pertinent to the economic needs of the Maltese Islands.

While economic needs are important, UM10C emphasised that the remit of university entities is to address industries' requirements and develop specific solutions that respond to our local challenges. They do so by "encouraging our academics to engage in research, which contributes to real life results that could be applied economically in collaboration with industry" (UM10C).

DLAP2F stressed that addressing economic needs should be integral to STEM uptake and careers by including stakeholders throughout the process.

> …The educational part is an integral part of the economy. It should not be disjointed from social constructs. This also includes processes and encourages the vision and collaboration of different stakeholders throughout the entire process, not just [as] an afterthought. (DLAP2F)

MCST4C emphasised that a knowledge-based economy depends on STEM: " People are constantly talking about creating a knowledge-based economy. But only if you invest more in areas like STEM. So, everything is linked." Furthermore, MCST4C emphasised the significance of stakeholder engagement in mitigating fragmentation.

> We do not necessarily emphasise the economic aspect when we speak about Esplora, but, together with our stakeholders, we are strengthening that aspect because the more people you have on board, the less fragmented the area becomes.

Subcode: 1.2.3 Scientific excellence

Scientific excellence plays a crucial role in setting policies and strategies at entities that conduct PES. This seems to be particularly true for UM:

> There are eight subdivisions (in the UM's strategic plan), and one of them is precisely to promote world class research…by encouraging scientific excellence. It is one of the highest priorities because, generally, as a university, we want to strive to increase our standards. (UM10C)

To meet these standards, UM11C emphasised the significance of providing students with "a meaningful learning experience that ensures our students are equipped with the right skills, knowledge and competencies at the time of graduation and beyond."

MCAST1 considers conducting meticulous and professional research following established research protocols in line with industry to advance the entity's reputation and visibility.

> We take pride in our research, and we do research in a very professional way…using the scientific method, what is required and being used in industry. We choose topics of interest, and our students then do their dissertations. In so doing, they are promoting MCAST. (MCAST1)

MEYR has tailored programs to support gifted students in mathematics, science, and computing through a range of focused activities: " It is a pocket of students which needs attention. We try to give them priority and resources and create activities which help to support them" (DLAP2F).

Although MCST does not conduct research internally, it demands scientific excellence from the scientists who receive funding through the Research Excellence Program established in 2020. Furthermore, Esplora values the experiential knowledge of the variety of stakeholders, including science centre visitors, as "…you need to recognise that different people have different talents. At Esplora, we want everyone to be on board regardless of whether they are high achieving, have high aspirations of becoming scientists or not" (MCST4C).

Subcode: 1.2.4 RRI and Community participation

In the context of research and innovation, the sub-codes Responsible Research and Innovation (RRI) and community participation are closely linked. Public engagement is one of the main pillars of RRI and community participation is one of the ways that PES interacts with citizens and stakeholders to understand their needs and goals better. This sub-code evaluates whether RRI – as a conceptual framework – is incorporated into entities' research and innovation policies/strategies. UM and MCST mentioned this driver since research is primarily conducted by UM and facilitated by MCST, whereas MCAST and MEYR did not mention it.

UM4 introduced an ethical dimension/responsibility into this debate:

> I think responsible research must keep in mind the rights of citizens to know what is happening (in research). In some areas, it may even require, if not necessarily, citizenry permission, but definitely state permission. The state, of course, reflects what the citizens want. It decides whether this (research) is acceptable, and whether…it is (probably) out of bounds. (UM4)

Adhering to research ethics guidance is important as "You cannot excel in your research's technical and scientific aspects if you ignore research ethics. Our research and the innovative products are driven by a responsible approach towards society in general" (UM10C). The UM highlighted this crucial element in research and innovation by setting up the University Research Ethics Committee. The UM is also "…committed to set up a research integrity office, which looks not just at the ethical aspects, but more about the integrity of the research in a more general sense" (UM10C).

According to MCST4C, RRI "…is something which is at the core of the MCST. I am going to link it to community participation" (MCST4C). A former MCST employee highlighted MCST's role within the community by "…[thinking of] setting up something similar to a science shop. We are [also] lobbying to get some funding to be able to support research groups within the island to conduct their own scientific research" (MCST3F).

In MCST3F's opinion, the government should allot funds to engage various publics.

> …we get around €30,000 from the government per year to be able to communicate science. Instead of using that €30,000 for us to communicate with the general publics whichever scientific topic we decide, we would like to extend a call to different publics – whether they are formal citizen society organisations or individuals, doesn't make a difference. In this way, they can tap into these €30k within our remit.

MCST1 emphasised the significance of community involvement facilitated by Esplora, stating that "obviously community participation is very important and that it is also related to STEM uptake because once you have community participation, there will be an increase in students…at various levels."

MCAST considered RRI to be linked to community participation and economic needs in research projects, and "…it depends on what the sector outside of MCAST requires. So basically, it encompasses economic needs, RRI and community participation in research projects. They are all together" (MCAST1).

For MEYR, community participation takes place through dissemination and outreach events organised regularly by the respective entities, with "each one of them that bear a lot of fruit and all are successful in their own way" (MCST4C).

UM researchers are obliged to disseminate their research when they are awarded grants either through MCST, EU projects, or internal funds (UM2). Citizens ' participation in research projects seems to be increasing. However, UM9F noted that participation at the local level can be much higher.

> Community participation, I think, happens in spite of, not because of, what we do…I do not think there is a concerted policy and a plan of how to engage…**in spite** of its grand old age and huge size in relative terms, it does not have a major presence in our local life.

Another UM staff member pointed out that community involvement is not always necessary, and the level of engagement may differ based on the research topic.

> Community participation in scientific projects is useful for certain types of research, not others. Epidemiological research is one thing; environmental research, where you need monitors as many as you can have, would be another where community participation is essential …you do not really need community participation to determine the structure of some material in the lab. (UM4)

Subcode: 1.2.5 Media

This sub-code explored the influence of media on research and innovation policies/strategies in entities that conduct PES. The study revealed that all interviewees from the diverse entities place significant emphasis on their entities' science communication policies, which are primarily guided by their own priorities rather than being influenced by the media.

MCST, UM and MCAST use and value the media because of its strength in disseminating their research (MCST4C).

At UM:

> The main [communication] strategies are principally through Think magazine and Newspoint and soundbites, which would also be available to the general public on the [UM] website. As far as media is concerned, we also [use it] very often when we have got projects which are funded, especially those funded through the MCST programs. (UM10C)

However, UM10C also emphasised that "…as a university we can, and need to do more when it comes to communicating our research and innovation achievements to the general public, using the media."

MEYR use the media to showcase what is being done in schools or to promote particular messages but although:

> We try to influence the media, but we are **not very good** at influencing it. Whenever we have activities, we show them in the Sunday newspaper, on a few sites on Facebook and on the internet…. [but] there are many industries which are much better than us when it comes to getting their message through the media" (DLAP3F).

The same feeling was expressed by UM3: "…we have some brilliant academics working on some very brilliant projects and normative aspects, as well as [ground-] breaking research, and most of it does not even make it beyond the four walls of the university." Similarly, UM10C voiced the same concern:

> I think we can do much more. The University Communications Office could help a lot in that respect, regularly through Newspoint within the University itself, which often shares news about research projects and research endeavours, and perhaps research successes as well.

5.2 Theme 2: Communication channels

Table 5.3 gives an overview of all the main categories and sub-codes for education and training.

Table 5.3:

Main categories and sub-codes for Theme 2 – Communication channels

Theme 2: Communication channels		
Main Categories	**Sub-codes**	**Description**
2.1 Communication channels	2.1.1 Print	Refers to scientific information that is disseminated in printed form.
	2.1.2 Online & social media	Refers to scientific information that is communicated through online and social media platforms.
	2.1.3 Visual/audio	Refers to science information that is communicated through visual and audio formats.
	2.1.4 Journal publications	Refers to scientific information that is disseminated through academic journal publications.
	2.1.5 Channels provided by the entity	Refers to scientific information that is disseminated through internal entity's channels.
	2.1.6 Newspapers	Refers to scientific information that is disseminated through newspapers.
	2.1.7 Meetings	Refers to scientific information that is disseminated through meetings with the publics.
	2.1.8 Radio	Refers to scientific information that is disseminated on radio channels.
	2.1.9 Events	Refers to scientific information that is communicated at events in different forms through dissemination, dialogue or participatory approaches.
2.2 Expectations by entities to communicate science	2.2.1 Increase uptake in STEM courses	Refers to the entity's aim to boost STEM course enrolment through science communication.
	2.2.2 Promote research and its results	Refers to the entity's aim to communicate science so as to promote research and its results.
	2.2.3 Acquire funding	Refers to the entity's aim to communicate science to acquire funding for their entity.
	2.2.4 Promote the entity	Refers to the entity's aim to communicate science to promote their entity.
	2.2.5 Recruitment	Refers to the entity's aim to communicate science to recruit employees.

Main category 2.1 Communication channels

Sub-code: 2.1.1 Print

This mode of communication was the least used by all the entities. UM mentioned that it has its quarterly printed magazine Think: "Think is the official UM publication which promotes primary research of a scientific nature. It is a blend of traditional media because it is also a printed magazine" (UM3).

MEYR try to adopt an environmentally friendly policy as much as possible and keep printing papers to a minimum.

> We use print media, like when we print posters, but we try to be as environmentally friendly as possible. When launching an activity, we make use of [online] letter circulars. We try to make sure that we reach out to the public in diverse ways. (DLAP3C)

MCST rarely use printed media and only uses billboards to communicate about important milestones: "Billboards are not something which we do advertise with on a regular basis. We will use billboards to communicate the next big milestone, which would be Esplora Natura. So we are very strategic in the way we market" (MCST4C).

Sub-code: 2.1.2 Online

All the entities use online media to communicate with various stakeholders, through emails, their own websites, online newspapers, and social media. While DLAP1 stated that they "communicate through circulars that are sent through emails to all schools", MCST2 also use "digital media. We are focused on our website and our social media platforms. We also have some influencers on board as well."

UM8F noted that:

> we have a strong presence on our website. So, we are using online media, significantly. We also have a Facebook presence, and there are research-oriented pages on scientific research. The information is there if you know where to look, but you must know where to look.

The challenge facing users when trying to find information on the UM website was also highlighted by UM6: "...when somebody wants to find specific information on the website, it is usually like a labyrinth, like a maze...it also happens to me, sometimes when I want something I use Google to search the university website."

All respondents agreed that social media are the most effective medium to disseminate information about events or research, particularly with the younger generations. Facebook is the social medium most commonly used by all entities. UM also mentioned Twitter.

Sub-code: 2.1.3 Visual

This sub-code explored modes of communication that use visual elements to convey ideas, information, and messages. Esplora uses videos to showcase particular messages – e.g. to encourage more visitors to the interactive science centre: "Esplora, launched the new brand [corporate] video. What made it more impactful than the other advertisements we had was the fact that we were telling a story" (MCST4C).

Similarly, DLAP1 stated that their use of videos "...depends on the nature of the initiative...they are [a] very good visual representation of what is taking place and perhaps what are the nest steps."

All entities use television as another medium to advertise their messages, courses, events, or activities:

> ...invariably, you will find the UM either mentioned officially as the spokesperson about something on your television but also increasingly through panellists on certain programs who are academic staff. (UM9F)

On the other hand, MCST2 use popular shows and "One of our biggest...investment is X-factor purely because we want to reach quite a lot of varied audience and X-factor is driven by a big audience" (MCST2).

Sub-code: 2.1.4 Journal articles

Journal articles are relevant to academics at the UM. Researchers are encouraged to publish in open access peer-reviewed journals with good impact factors. Besides elevating UM's ranking, these publications also serve another purpose: "Publications in an academic journal that will earn you your promotion, at the end of the day, I think that mainly science is communicated through academic journals" (UM5).

However, while publishing in academic journals is a good way for researchers to progress in their careers it is not reaching other audiences:

> Academics want to publish in academic journals, which stands to reason, but the community at large does not bother with academic journals. We need to rehash the technical jargon being used in these projects and translate it into simpler language that people can understand, relate to, and realise that the university is not an ivory tower. (UM3)

Sub-code: 2.1.5 Channels provided by the entity

UM has its own channels to communicate internally and externally. UM communicates externally through Think magazine. Internally, news is spread through Newspoint, an online portal accessible to everyone and UM's radio station, Campus FM. However, UM3 questioned the website's popularity, "...I very much doubt how people actually browse through the University website to see what is happening."

For MCST, "When it comes to channels of communications [about research and science] probably, the most effective tool is mainly Esplora…" (MCST1).

Sub-code: 2.1.6 Newspapers

All entities use newspapers to communicate with citizens about their relative science events, research, or entity. This has now transitioned to an online format as well. Newspapers are not as popular as in previous years because "…traditional media – radio, newspapers, they're fading" (UM6).

UM is heavily involved in producing a Sounds of Sounds page on the Sunday Times of Malta and some academics also have their own nespaper columns (UM4). However, "…the sections that we get on the Times of Malta at least put us out there, but unfortunately, we do not know how many people are reading those articles…" (UM8F).

Sub-code: 2.1.7 Meetings

This section covers meetings held with citizens, as opposed to work related meetings. All entities hold meetings to communicate with their stakeholders. MCST holds stakeholder meetings, which target specific groups and indicated that: "…civil society as a whole was involved, was consulted, was given space to give its feedback with regards to the setting up of Esplora" (MCST1).

Sub-code: 2.1.8 Radio

Radio advertisements are still used to communicate with citizens about events and science research, even though this medium is not very popular with the entities or with citizens (MCST1 and UM4). Although UM has its own radio station called Campus FM, where science is communicated through snippets on various radio shows, UM10C questions its impact:

> Campus FM is also another important source. Again, I'm not sure what impact it makes out there to the general community, how many people actually follow those programs, and whether they find them interesting or useful. I guess it is up to the radio channel itself to do this kind of research right.

Sub-code: 2.1.9 Events

The most popular national event mentioned by all the entities was Science in the City. Science in the Citadel was also mentioned as a way of reaching out to publics. Other events mentioned included (UM11C):

STEAM (a 10-day intensive summer school in Science Communication);

Malta Café Scientifique, set up by the Malta Chamber of Scientists in collaboration with UM;

CineXjenza (a series of regular film events followed by a discussion with experts, run by the Malta Chamber of Scientists, and supported by Spazju Kreattiv, UM and Agenzija Zghazagh

Various final year exhibitions, such as the exhibition by the Faculty of ICT and Faculty of Engineering;

Participating in conferences such as the Med Tech Conferences; and

Various discussions and workshops, such as the recent Women in STEM organised at Spazju Kreattiv

MCAST1 also mentioned MCAST's participation in Science in the City, open days, Think Café and beach clean-ups.

MEYR organised several outreach events for researchers, students, parents, and citizens to participate in, such as (DLAP3C):

- International STEM awards;
- Tikka Matematika;
- X'hemm għal dinja aħjar;
- Online or in-person primary science webinars
- Little Big Maths Talk;
- Junior High Five Maths Channel Challenge; and
- The STEM Career Expo

Esplora's strategy emphasises in-person visits to the centre. Nevertheless, this approach does not limit its particiaption in other events, including Science in the City.

> We want people to come here and visit Esplora…this is surely part of our ethos. But we are very strategic so that we would be present in SITC [Science in the City]…it would be a miss for Esplora not to be part of such an important national activity. (MCST4C)

However, MCST4C criticised the level of technical jargon being used during SITC:

> …these were my colleagues, and I was watching them, presenting an experiment…They were using jargon that even I, a person coming from physics, could not understand. Because I have a limit as well to my physics knowledge.

MCST houses their own STEM Career Expo and other dissemination events for researchers, industry, and citizens:

> In January, we have the STEM Career Expo. If we are engaging seniors for our seniors' programme and they are taking care of their granddaughters or grandsons, that might somehow help. (MCST2)

Main category 2.2 Expectations by the entity to communicate science

This category explored the reasons behind the entities' willingness to communicate science to their chosen publics.

Sub-code: 2.2.1 Increase uptake in courses in STEM

Interviewees have revealed that one of the primary reasons to communicate science with citizens was to encourage more students to take STEM courses. In this context, the following sub-code examines their expectations of how and who should be targeted to attract students towards STEM courses.

Both MEYR and Esplora are working towards dismantling stereotypes to increase students' potential to enter STEM courses. Their objectives are to collaborate with students, their parents, and guardians to eliminate barriers related to STEM education.

> I think that STEM affects the choices we do in life, the lifestyle we adopt, so it is important to communicate this to all, and to rope in citizens in this process. (DLAP1)

> Citizens are afraid of it because their only experience [of STEM] is when they were at school. So, we work directly with schools, and indirectly, with the general public. (MCST2)

MEYR embarked on 'My Journey', which "…is basically an exercise that helps Year 8 [11/12-year-olds] students choose the subjects that they will keep on studying in Year 9 [13/14-year-olds] and 10 [14/15-year-olds]which will lead them to their career of choice" (DLAP3C).

UM8F reported that the process of attracting students is managed autonomously by each STEM Faculty. These faculties aimed to attract students from a restricted pool of individuals who have already taken up STEM subjects at earlier levels. UM8F noted that "The Faculty of Science has been successful in increasing numbers, whereas the Faculty of Engineering and, to some extent, the Faculty of Information and Communication Technology (ICT) have seen some decline."

MCAST1 noted that "…there are new careers in science and opportunities but not everybody unfortunately is aware of these, so I think we need to promote it further." Through popularisation, MCAST is also actively addressing a deeper issue:

> There is a stigma that science subjects are a bit difficult or are for a chosen few, for the most academic and high achievers. We are constantly participating in a lot of things so that we can remove the stigma, because science is actually for everybody. (MCAST1)

Sub-code: 2.2.2 Promote research and its results

Science is communicated to various publics to promote research and its results, as stated by MCST, UM, and MCAST. MCST is responsible for communicating the importance of research and innovation. Disseminating research helps raise awareness about specific topics and demonstrates the significance of research and innovation to society, both locally and internationally. One such example "…is about cancer research by local researchers, another about reusable resources and memory storage and about technology which helps speech impediment in children" (MCST2). To ensure that the research is communicated to citizens, a one-day seminar was held at Esplora: "We identify the target audiences, send invitations and invite the general public through social media…we have around 80, which happens to be quite well attended" (MCST2).

UM's academics are expected to conduct and generate research and "…create knowledge, not just teaching knowledge. This leads to innovation, new results, discoveries, and so on….to increase awarenss out there with the different stakeholders and actors" (UM10C). UM8F identified other important aspects of promoting and showcasing research conducted at UM:

> We want to educate the people in government, who hold our purse strings, about the necessity and the worth of doing research at UM. We also want to engage with industry for example, because companies are unaware that the UM can help them, from a research perspective.

Sub-code: 2.2.3 Acquire funding

This sub-code examines how entities communicate to acquire funding. MEYR and MCAST do not indicate this need, whereas UM does because "…to engage in research, we need to make sure that we have enough funds. Funds are never enough; we always want more funds, but we definitely need to generate more specific funds for research" (UM3). UM8F identified three ways how UM acquires funds for research:

> So, A are national funds…which should be greater than the funds that we get through competitive funding because that is what happens all over the world. B are funds that we get

> through competitive funding abroad. C is a new phenomenon that we are seeing where academics are directly approaching ministries and NGOs and conducting work with them.

UM7 stated that one of the resaons for involving citizens in science is to increase the likelihood of obtaining additional financial support for research endeavours: “I remember a discussion I had with the minister many years ago, when I was sort of complaining or moaning about how little the government devotes to research. He told me: ‘Yes, work on the general public’”.

Activities such as Alive Cyclists campaign organised by the Research Innovation and Development Trust (RIDT) of UM, are popular because they are directly linked to citizens’ wellbeing and UM4 noted that it makes it easier to ask for funds:

> …the RIDT activities, witness the campaigns that cyclists do, and people seem to be willing to support those…you can easily win over people’s interest and support for something that all people feel is a threat to them…everybody fears cancer and will someday strike him or her, so they want to be engaged in fighting it. (UM4)

UM4 feels that UM has a duty to ensure that locally conducted research is relevant to society.

> It will be a very bad day if stakeholders or taxpayers come to realise that perhaps too much of their money is going into frivolous things and that the university is not spending money wisely. The UM is employing people to do research or … employ[ing] academics whose research has no relevance whatsoever to perhaps the livelihood or the quality of life of the stakeholders. (UM4)

Sub-code: 2.2.4 Promote the entity

One of the outcomes of commcunicating science for MCST and UM was the entity’s self promotion. MCST1 highlighted the advantages of having an interactive science centre as a communication tool:

> Our main and most important available tool to MCST is Esplora. This is a unique thing as it is not normal in any given country to have a science council which has the luxury of having an interactive science centre at its disposal to communicate what is being done.

MCST3F expressed the need to demonstrate to the Maltese residents the importance of having an interactive science centre and highlt its accomplishments relative to other EU member states:

> …we are very interested in the number of people coming through Esplora…not because we are interested in keeping ourselves financially sustainable, but because we want to show that Malta is top [in everything] when it comes to other European countries…showing how much we have grown.

The UM's comunication strategy included disseminating scientific knowledge to enhance the entity's visibility and reputation across local and global platforms thus increasing its international ranking. Disseminating results also attract potential collaborations with industry (UM3).

MCAST1 elaborated on MCAST's strategy to involve industry:

> …we are in continuous contact with industry. We even involve industry during our cyclic review of the courses because what was important and high on the agenda three or five years ago, might not be there today, and we might tweak our courses to be more suitable to what industry needs and what is out there.

MCAST1 mentioned how MCAST employees participate in open days: "…we have a lot of staff who volunteer to come in their own time, to promote MCAST. We have requests from schools, from Local Councils, so that somebody [from MCAST] goes to talk to the general public."

Sub-code: 2.2.5 Recruitment

The study examined how entities aimed to communciate with prospective researchers or students who can contribute to the future workforce. Both MCAST and UM use science communication as a tool to attract talent: "We need to have people who actually know what is going on and how to solve problems. We need youngsters with a lot of motivation" (MCAST1). UM is bringing in researchers from other countries to enhance its academic environment.

> The raw uptake of sciences is decreasing I hear, it is worrying because unless we have our own people who are taking science seriously and who are willing to research etc, then we need to import [researchers], but I do not think it is a bad idea to import researchers. It can enhance the academic environment. (UM5)

5.3 Theme 3: Education and Training

Table 5.4 outlines the two primary categories and their sub-codes examined in this study. The entities under investigation impart knowledge to their audience through formal or informal methods. It is worth noting that the interviewees did not mention non-formal education and, therefore, was not considered during the analysis.

Table 5.4:

Main categories and sub-codes for Theme 3 - Education and training

Theme 3: Education and Training		
Main Categories	**Sub-codes**	**Description**
3.1 Formal and Informal Education	3.1.1 Formal Education	Refers to how science education aims to provide a well-rounded understanding of various science subjects, develop critical thinking, and include practical skills.
	3.1.2 Informal Education	Refers to knowledge that takes place outside of educational entities through dissemination, dialogue and participatory approaches.
3.2 Training	3.2.1 PES training	Refers to training that aims to impart practical skills and prepare individuals to engage publics with science.
	3.2.2 Professional development	Refers to professional development courses that concentrate on engaging the stakeholders of different entities with science which encompasses broader career aspirations and personal growth.
	3.2.3 Conferences	Refers to training that takes place at PES conferences through workshops, seminars, dialogues etc.

Main category 3.1 Formal and Information Education

Sub-code: 3.1.1 Formal education

The sub-code delved into the formal procedures and strategies employed by entities to educate their stakeholders. The interviewees, including MCAST, UM, and MEYR representatives, focused on the formal aspect of education. DLAP1 further elaborated on the teaching of STEM education in schools as being "…relevant and valid to the changes and the realities in industry and in careers, such that STEM education and the way industry evolving are kept aligned" (DLAP1).

DLAP1 also noted that it is essential to ensure that the teaching methodology aligns with the latest developments in the field to ensure that "…students from a young age are participating, are actually engaged in learning science in an interesting, engaging way, that helps to motivate their participation, their interest, and their further participation in the long run" (DLAP1).

Teacher professional development courses were identified as a formal way to better their practice.

> We invest a lot in training because we believe that the formation of educators who are going to the classrooms is never enough. There is the Education Officer at the forefront who is always driving the training, and where we do not manage, we have the Institute for Education, or we liaise with the University…we also have partnerships with MCAST and other entities such as ITS. (DLAP3C)

MCAST also regard formal education as an important element and one of their mission statements. This aspect is happening through the students' science course content (MCAST1).

UM4 indicated that UM aims to educate its students through its scientific courses in the various faculties and institutes. Furthermore, UM boasts of its commitment to providing top-tier education and equipping students with the necessary skills to excel in their respective fields:

> It is also about the quality of those degrees…it becomes even more important as the landscape becomes more cluttered with competitors…Within this increasingly crowded market, we must position ourselves in such a way that our public engagement of science is respected as coming from the brightest and ablest. (UM9F)

UM6 mentioned the flipped classroom as a pedagogical method "…that gets the student to talk. Some of our students have problems to discuss, …to present their ideas and to defend them when they are challenged." UM10C mentioned that in 2017 "the University set up a Doctoral School, specifically meant to ensure that our doctoral students are supported…and that standards are kept when it comes to doctoral studies…"

Sub-code: 3.1.2 Informal education

This sub-code analysed data pertaining to informal science education programs and activities offered by different entities. Although all the entities engage in some form of informal science education, Esplora stood out as the only entity solely dedicated to provide informal education to students or citizens. Esplora's main objective is to entice citizens to visit their science centre by presenting science in an attractive and relevant manner through informal channels.

> Teaching is not the priority of the Science Centre. Because teaching is something that most people associate with what happens in the classroom. We do teach, but in a very particular way, not in the traditional way that people understand. (MCST4C)

Esplora is used as an avenue to disseminate and communicate what projects and research are being done at MCST. The centre's remit is "…to get science out of classrooms, and not just books…that science is something that you can do and what you are already doing in your everyday life" (MCST3F).

MCST4C feels that such an informal space can serve to encourage citizens to engage with science because:

> Esplora is a platform where people can enter comfortably knowing that they're not going to be judged about their science knowledge, they're here in a science centre that offers them with a completely independent and interactive experience.

MEYR have various initiatives targeting other stakeholders besides schools and educational entities and regards scientific literacy as vital in today's world (DLAP2F). MEYR utilised television spots as an informal means of citizen outreach. One of these campaigns focused on promoting STEM careers, with a MEYR representative highlighting the diverse range of STEM opportunities available and emphasising that a university degree is not a prerequisite for advancement in this field:

> You will always find ways of informally motivating the public even with spots on television…we had a television spot promoting STEM careers. Viewers will say that, for example, nowadays sport can integrate with STEM careers such as physiotherapy. There are endless possibilities. (DLAP3C)

UM1 listed the informal activities that UM STEM academics and employees are involved in: "CineXjenza, Café Scientifique the science page on the Times, Campus FM." UM10C also mentioned that "the doctoral school holds an annual event to educate the general public…showcasing the PhD students' research, its impact, its use and so on."

UM7 ascertained that:

> If you want to educate an audience, you must find ways to engage them. So, you have to present your ideas in a way that they or at least five of them can understand and, more importantly, appreciate them by members of the audience. (UM7)

The Committee for Research Engagement (CRE), also set up by UM to educate relevant stakeholders about research and innovation, tries "…to educate the market and to optimise the way that we engage with the stakeholders" (UM8F).

Another way of reaching out to various stakeholders is through UM's own students who graudate and act as informal ambassadors for UM in their workplace:

> We have people now, who are working at the OPM, ministries, Malta Enterprise and through our own postgraduate programmes, we are training the entrepreneurs and when they go back to their organisations, they are increasing the level of awareness there. I think that would be another channel that we have to exploit. (UM8F)

Despite active efforts to communicate UM research and promote STEM education to students, UM3 highlighted a potential issue:

> We need to do it in a structured manner…most of it is happening in a haphazard and ad hoc manner. We can achieve much more and better results if we [communicate science] informally, **but** in a structured manner.

The UM employees interviewed perceive engagement and communication as integral components of their academic responsibilities (applicable to scientific officers, research support officers and other STEM-related positions). Nonetheless, UM4 revealed that not everyone shares this stance at UM for example if:

> … [you] have this person who is wasting her time doing these trivial things and communicating with the nation through television and newspaper articles. Why doesn't she spend more time on campus, being more available for her students, and spending time in research in a library or the lab? I have heard from my colleagues about these kinds of externalisations, and it is a pity because we do not seem to understand that one of the scholarships of the academic is the scholarship of outreach, and this is outreach, of course, at its best. UM4

For MCAST1 "there are different stakeholders. You **have to** eduacte and promote science differently depending on the stakeholders' expectations and stakeholders' background." Moreover, MCAST1 indicated that active participation by their staff members in science open days, fairs, think cafes and other industry events is important for maintaining a strong connection with current industries to ensure that students at MCAST remain up-to-date and relevant.

Main category 3.2 Training

This section explores the various modes of training offered by entities for science engagement with diverse audiences.

Sub-code: 3.2.1 PES training

There seems to be a lack of specialised training for employees of the various entities to effectively communicate scientific advancements and research to citizens, except for Esplora "…on average we send staff abroad for training…but we also get [people from abroad] to come and help us on how to best to engage visitors with low levels of scientific background" (MCST2). MCST4C said that "…job shadowing is something which we have been doing since the start and we continued with this approach." MCST4C further explained the direction of how Esplora Natura will also provide training to its staff members:

> It would also be interesting for us now to engage on a plan how we are eventually going to train the new employees of Esplora Natura. Using our contacts, our network, but at the same time using our in-house expertise as well.

MCAST, UM, and MEYR, confirmed that training is only provided for specific target groups: "There has been no specific training as such but a lot of learning by doing" (DLAP1). DLAP2F further asserts that:

> There may be some NGOs who are working in these areas, but officially within the DLAP we do not have this kind of training for our staff or for anybody else. It is a pity because the only information that sometimes trickles is through media and that is not always correct.

UM4 felt that staff are not being trained to communicate effectively. UM5 emphasised the significance of using plain and simple language while communicating scientific information to citizens: "…you need to somehow explain complex economic and political matters, to individuals such that a ten-year-old or a sixty-year-old can understand you. You need to simplify…not taming [or dumbing] it down, but **simplify**" (UM5).

UM3 pointed out: "I did not really come across programmes for specific training earmarked for academics, educators, influences for how they can go about communicating scientific research to society at large." UM2 expressed dissatisfaction with the lack of proficiency in effectively communicating scientific infromation: "One of the things that is mising in our faculty is learning how to talk to people. …So, communication, at least in our faculty, is not given the top priority. We learn by trial and error, basically."

While the staff at UM lacks training opportunities, UM3 noted that the Communications Office is actively "…trying to communicate meaningful scientific resarch in very simple language and its potential effects to society." UM7 highlighted the absence of incentives for communication efforts among the university's employees, particularly the academics, and recommended incorporating it into their career progression under the collective agreement.

According to MCAST1 there is no formal training program: "Given that there are certain people who have a lot of experience, they normally tend to informally teach and train the other staff and the people on how to go about it." However, MCAST identifies another training opportunity for MCAST staff: "Our lecturers and our staff can go on Erasmus+ [courses or exchange programmes], and they choose different areas where they can participate and where they can [im]prove their knowledge."

DLAP2F was dissatisfied with the quality of radio content and suggested effective training and outreach to encourage citizens' interest in science and research.

MCAST does not provide specific training for engaging with citizens but encourages participation in PES activities. "Staff are encouraged also to participate in these activities and also to attempt lectures, activities and participate in opportunities where they can communciate with citizens" (MCAST1).

While training is not available for UM staff, UM7 drew attention to the launch of the undergraduate BSc in Science for Education and Communication programme that prepares students to engage with various audiences. There are also science communication workshops available to students and UM employees through the doctoral school.

Sub-code: 3.2.2 Professional development

This section explored professional development courses that concentrate on engaging the stakeholders of different entities with science. MEYR provides its educators and staff with the essential skills to communicate effectively with their students. "…there is a lot of professional development for teachers... for other educators within the ministry that is ongoing" (DLAP1).

MEYR offers professional development courses with peer learning activities in various countries, including European Schoolnet:

> Pre-learning activity (PLA) is when a country wants to showcase the good practices that are happening…This PLA usually involves going to schools and experiencing what is being shown. I have always found it a very good learning experience whenever I went to schools abroad. (DLAP2F)

Esplora train its staff in how to effectively communciate science with citizens of all ages. This training serves as a crucial component of their employee's professional growth and can be delivered in-house or through external channels:

> There is training available within Esplora too. They give training on how to be better science communicators, through the UM lecturers, they also give the opportunity for staff members to carry out [certain credits] within University to engage better with society, civil society. (MCST3F)

Esplora also seemed to highlight the significance of utilising storytelling and artistic methods to convey scientific insights to diverse audiences effectively:

> Storytelling is one of the main general art forms with which we try to engage, that is why we say STEAM…We send 6 people to a bootcamp…and when they come back, they share what they learned with other staff. (MCST2)

UM requires new academics and those seeking promotion to complete a continuous professional development (CPD) course (UM9F). UM9F also shed light on the content of these courses: "…teaching techniques, communciation techniques, alternative assessment techniques. So presumably within that they become better able to communciate scientific research to citizens. But it is an indirect route." And from a personal perspective: "At the moment I am doing the CPD. We had a one-hour session, and a little bit on how to communicate. That is about it" (UM1).

UM2 raised concerns regarding the timing of CPD as by the time academics undergo CPD, they are most likely already teaching in a manner like their supervisor, rendering the CPD process somewhat redundant. "CPD happens too late, at least for me, it happened too late in the day to make any significant change…It should be given within a year that you start lecturing" (UM2). UM1 referred to the work of another UM academic involved in outreach with the Institute of Electrical and Electronics Engineers (IEEE) and training computing teachers:

> …on how to give guidance, he uses the IEEE material, and they have specific courses, kind of train the trainers. I believe that at one point, he managed to get a certain course that is valid as an in-service training that teachers are required to take. (UM1)

MCAST also holds regular CPD programmes for their staff "…apart from the academic part of delivering lectures, etc." (MCAST1).

Sub-code: 3.2.3 Conferences

This sub-code explored conferences to train staff at the entities conducting PES in this study.[19] Esplora is the only entity that sends some of their staff specifically to science communication conferences:

> …we go to conferences such as ECSITE [European Network for Science Centres and Museum] or EUSEA [European Science Engagement Association] or occasionally we also find specific courses for examples, we just sent 6 people on how to use and become more skilled in storytelling. (MCST2)

5.4 Theme 4: Personal vision for PES

This section focuses on the interviewees' personal vision for PES (see Table 5.5).

Table 5.5:

Main categories and sub-codes for Theme 4 – Personal vision for PES

Theme 4: Personal vision for PES		
Main Categories	**Sub-codes**	**Description**
4.1 Personal vision	4.1.1 Researcher interviewees	Refers to researchers' personal views.
	4.1.2 Interviewees in senior management positions in communication	Refers to senior management positions in communication's personal views.
	4.1.3 Interviewees in senior management positions in academia	Refers to senior management positions in academia's views.

Main category 4.1 Personal vision

Within this category, my study delved into the interviewee's personal vision to determine if it was congruent with their entity's vision. The interviewee's anonymity was respected throughout the process as the interviewed individuals held positions in senior management, in communication and research roles. Personal visions were explored in accordance with their respective roles within their entities.

Sub-code: 4.1.1 Researcher interviewees

Researchers interviewed in this study indicated their need for resources, knowledge, and expertise to conduct PES. Further support would be able to assist researchers with the necessary skills and tools to engage various publics and stakeholders.

[19] While no UM interviewees mentioned people attending science communication conferences, both myself and other UM employees have attended various science communication conferences.

> I would like to see that we have enough human resources, and backed with knowledge so as to be able to create the necessary resources to carry out public engagement so that we do not have to spend that much time on engaging with the public. (UM1)

UM7 stressed the need to provide training to academics:

> … there should be a unit at the university that tackles this and provides this essential service…the academics are hopeless in front of people…some people are born gifted and need little education…. The majority need help and even if they are given a lot of training, they still will not be fantastic public speakers, but they will get better.

UM1's vision was to be officially recognised for their outreach and engagement activities as part of their career development. This would reward their efforts and encourage them to engage audiences regularly.

> Ideally there would be some form of policy, the collective agreement states that we would be "rewarded", for the number of hours or activities that we would engage in. So that it is considered as part of what we do. (UM1)

During certain periods such as exams, UM1 noted that outreach activities should not be prioritised over other duties, leading to potential imbalances between work and personal life.

UM2 did not show any difference between personal and entity's visions, but was open to collaborating with industry in the future.

> I am not sure if there is a difference between the vision of my role and my personal vision. What I would like to see though is having more of our projects being supported and applied by industry. (UM2)

UM2 aimed to offer constructive guidance and positive influence in the lives of children of diverse ages to foster and promote positive choices.

> I would like to be able to influence a lot more students, even younger students… to be able to say - I did something good for these children…to look back and have someone saying, listen, I made this choice because you influenced me. (UM2)

Sub-code: 4.1.2 Interviewees in senior management positions in communication

In the sub-code, senior management interviewees' outlooks in communication were analysed.

UM3 suggested that technology has led to a decrease in students' motivation to participate in the demanding procedures involved in studying science.

> … technology has made the younger generation lazy … to get a seat at university in some of the science-based subjects is no easy feat and we are getting **less** students at the age of thirteen, choosing science subjects. The more we dabble with education, the more options we introduce, is affecting student uptake. … we should be careful with education even in the earlier stages if you want research to flourish even more. (UM3)

UM3 expressed concern about the potential impact of vocational subjects on pursuing traditional science subjects, which could ultimately affect the academic field. However, UM3 underscored the significance of effectively communicating research to citizens.

> We are dissuading youngsters from engaging in the traditional scientific subjects because of vocational subjects. Being an educator myself there is a risk that less people will be enticed to follow the traditional paths that ultimately lead to research and scientific breakthroughs. We need to be **very** careful. However, the more we communicate, the more people will be aware and that is what is important. (UM3)

MCST1 emphasised that the proposed plan for investment in scientific and research innovation will be executed according to their vision.

> "…there is one thing that I would like to see happening before I pass the baton over to someone else, perhaps when it comes to running the science councils that we reach the aims that we ourselves have set out for us when it comes to scientific and research and innovation in our country as a percentage of the total GDP. (MCST1)

MCST2 suggested the establishment of a dedicated Ministry for Science, Research, and Innovation, like those existing in other countries, that would be the driving force in promoting science. Furthermore, MCST2 stressed the need

> … to have a single driving force in the country which tackles research and innovation and STEM, where credit is given to whatever is being done with the support of others and while this is difficult it is not impossible.

MCST4C also echoed this stance: "… to have less fragmentation … and to have more people working together towards a common goal". Moreover, MCST4C provided a reason why people do not work together effectively:

> … we fear that one person is going to take precedence over the other. … Perhaps it is embedded with our traditions. The fact that even a household has one leader. We always have this perception of one leader. I lead. You follow. If we join forces, will this make me look weak? Will this be perceived as an indication that I cannot do or implement something? … which is **definitely** not the case.

MCST3F highlighted the importance of citizen participation in determining which research projects are funded:

> "…people as well have the right, and government has the responsibility to give some power to people on this, pending on government funding when it comes to research. For example, we do not have much money that is being syphoned through research, but I think some of that needs to be informed by the public's needs.

Sub-code: 4.1.3 Interviewees in senior management positions in academia

STEM education for all was proclaimed to be an important personal vision for DLAP1: "My vision is to keep the communication about science open to all … we can no longer proclaim or portray STEM education as an option open only for some" (DLAP1).

All the senior management positions interviewed in this study believe that publics have a right to know and be involved in ongoing research and that researchers have to do so as it supports their salaries. Some of the interviewees indicated that more time needs to be dedicated towards public engagement. Since science is prevalent and impacts every aspect of our lives, PES could assist with the decision-making process between scientists and citizens.

> PES provides opportunities for meaningful interactions and for mutual learning between scientists and members of the public so that the decision-making process is informed with different and wide perspectives. (UM11C)

> We need to start communicating the importance of STEM education to all citizens because whatever your role, career, gender, or course of studies, you will be needing STEM in whatever role you occupy. (DLAP1)

It was expressed that having a comprehensive strategy and vision is necessary to involve stakeholders effectively. Senior management in academia also emphasised the importance of engaging stakeholders throughout different phases and contexts of science, research, and technology, echoing the sentiment of interviewees involved in communication.

> I am all for involvement of stakeholders … the message will be richer, **more** consistent and accepted by the general public, if all/more stakeholders were to collaborate … nobody can do it alone … because nobody will succeed. We need a concerted effort by lots of people working together consistently. (DLAP2F)

> My vision concerns civil society and a series of societal and other stakeholders. … Progress at a national level, etc. including non-state, civil society and industry that can also be drivers. So, we need to give more value to their role, and bring them on board, so that we work together, create, and generate momentum. Regarding gender and STEM, we need to achieve a degree of critical mass to garner critical influence and to achieve something to progress in that area. (UM5)

MCST4C mentioned their ambition to include stakeholders through a stakeholder committee, which would help make decisions about content development and allow for stakeholder engagement. Throughout the duration of this thesis, it was observed that the senior management across all interviewed local entities experienced considerable personnel turnover. This phenomenon may indicate an exacerbation of fragmentation, leading to the potential discontinuation of projects and ideas

5.5 Conclusion: Summary of the qualitative results

This section presented the findings of interviews conducted with researchers and senior management from four entities: UM, MCAST, MCST, and MEYR. All entities indicated a shared commitment to engaging a diverse range of stakeholders with science, through both formal and informal channels. However, the specific type and focus of engagement varied depending on each entity's priorities and vision. It was noted that informal science education and engagement is currently fragmented and lacks a cohesive strategy. As such, there is a need for collaboration and the development of a common approach. Consistent with the findings discussed in this chapter, Entradas's analysis (2021) reveals that science communicators perceive public participation as encompassing two interrelated concepts: establishing trust and promoting transparency and openness within the scientific institution. Incorporating the perspectives of all stakeholders impacted by a decision is essential for rectifying the power dynamics among interested parties (Habermas, 1973). This approach underscores the importance of fairness, emphasising equal access and the empowerment of participants within the decision-making process. Furthermore, Roche et al. (2023) highlight that effective science communication education in higher education plays a crucial role in fostering these values by equipping future communicators with the skills necessary to engage diverse audiences. They argue that addressing local challenges while learning from global practices can enhance public trust in science, ultimately supporting a more inclusive and participatory scientific culture. This synthesis reinforces the need for educational frameworks prioritising transparency and stakeholder engagement as fundamental components of effective science communication.

Chapter 6

Qualitative results:

International public engagement with science network interviews

6.0 Introduction

Chapter 6 explores the data collected through 11 interviews with senior management staff from various institutions that engage with PES. The following two themes were identified during the analysis, each with sub-codes as shown in Table 6.1. Subcodes were identified through deductive coding using the codebook and even further through inductive coding.

- Theme 1: Network level: Governance and management
- Theme 2: Community level: Relationships

6.1 Theme 1: Network level - Governance and Management

Table 6.1:

Main categories and sub-codes of Theme 1

Theme 1: Network level: Governance and management		
Main Categories	**Sub-codes**	**Description**
1.1 Governance structure	1.1.1 Governance model	Refers to how a PEN defines the roles, responsibilities, policies, and procedures that direct, manage, and control it.
	1.1.2 Decision making	Refers to how a PEN makes its decisions based on the structure of the PEN.
	1.1.3 Challenges in structure and structure change	Refers to the challenges in the current structure of the PEN and whether the PEN proposes and is willing to change its structure.
	1.1.4 Effective governance structure	Refers to whether interviewees think that their current governance structure is effective.
	1.1.5 Topics discussed and documentation of high level-meetings	Refers to topics the variety of topics discussed at high-level PEN meetings.
1.2 Management and leadership	1.2.1 Shared values	Refers to the shared values of the PEN's management and leadership such as trust, commitment, openness, and inclusivity.
	1.2.2 Effective management and leadership	Refers to the factors that show how effective the PEN's management and leadership is.
	1.2.3 Funding and distribution of funds	Refers to the PEN's funding streams and how the funding is distributed within the PEN.
	1.2.4 Evaluate network	Refers to whether the PEN evaluates its own network.
1.3 Policies	1.3.1 Institutional and EU policies	Refers to institutional and EU policies that affect the management and leadership of the PEN.

	1.3.2 Internal policies	Refers to internal policies that affect the management and leadership of the PEN.
	1.3.3 Policies that hinder/encourage participation in science communication and the PEN	Refers to inclusive policies that either hinder or encourage participation in science communication and the PEN.

Main category: 1.1 Governance structure

Sub-code: 1.1.1 Governance model

This study explored the formal and informal PEN governance structures, including various hierarchical structures. The analysis considered only the lead organisation and network administrative organisation (NAO) models.[20] Based on the responses from the interviewees and the information from the PEN websites, it was determined that all 11 networks had a lead governance structure with a hierarchical structure, except for one that resembled a network administrative model.

A lead organisation network model is responsible for setting the agenda, making decisions, and allocating resources. In a lead network, effective network governance requires a centralised organisation within a network to act as the lead or hub for critical issues that are essential for the network's long-term maintenance and survival. Global Network 3 "is primarily operated through an elected scientific community. So, it is elected from the organisation's members [of Global Network 3]."

For a network to effectively lead its constituent organisations, it must be capable of facilitating agreements among them. This is exemplified by Trans-national Network 1, which includes a representative from United Nations Educational, Scientific and Cultural Organisation (UNESCO) on its board. Likewise, EU Network 1's status is reflective of its country's regulations.

Subcode: 1.1.2 Decision making

Decision-making processes at the higher levels of management varied depending on the governance structure, with decisions made through board members at the top level, down to members' and stakeholders' decisions.

Higher management tends to decide authoritatively how funds are to be allocated for conferences and workshops, and this is not a democratic process, "The funds are up to the board of the network so they decide the costs of the conference and workshops together with the person who is part-time" (National Network 3). This seems to be prevalent in most networks, be they national, global, trans-national, or

[20] A network administrative model is lead by governments and is part of government structure in a country NAO model. The basic idea is that a separate administrative entity is set up specifically to govern the network and its activities. Although network members still interact with one another, as with the lead organisation model, the NAO model is centralised. A NAO was established, either through mandate or by the members themselves, for the exclusive purpose of network governance. The NAO may be a government entity, or a non-profit, which is often the case even when the network members are for-profit firms.

European trans-national. Similarly, for the NAO-run network: "the ultimate decision-making power for the network is at the programme office housed at [government agency] headquarters as it is the primary funder… but [the government agency] would take into account the information provided by the office and the community" (Global Network 1).

Global Network 2 stated that "it is not a democratic process at the moment; we don't have votes regarding the network – It is an informal agreement; we all work on the same idea. People take different responsibilities." The general assemblies are an intricate part of National Network 1, and decisions have "… to be approved by the general assembly….if there are issues we discuss with the board as it really involves half the members." For EU Network 3, the decisions are also taken by the national representatives of the different countries: "in a country, we sometimes have a deputy representative forming part of the steering committee…similar to a board of directors"

Sub-code: 1.1.3 Challenges in structure and structure change

In this sub-code, the focus was on the interviewees and their observations regarding the structure of their respective PENs, including any challenges they faced and measures taken to address these issues.

National Network 1 outlined the difficulty of maintaining higher management continuity and ensuring long-term sustainability: "For example, my presidency term expires in May, and we do not know if there is going to be another one after me, but that is ok… I see my role as founder/president in ensuring the proper statutes and education." Another challenge identified was that "there are no behind-the-scenes/handover official documents," resulting in the need to hire someone to provide direction when the governance structure changes (Global Network 2).

EU Network 2 identified PEN members' expected and appropriate level of involvement as a potential issue. This includes day-to-day matters or submitting EU proposals. Additionally, EU Network 2 expressed concerns about the costs associated with high-level participation, stating that "involvement costs a lot of resources at the top level from the management level to organise this [level of participation]."

Global Network 4 highlighted challenges related to committee members' understanding of their involvement, as there are no clear guidelines for their roles and expectations. Similarly, Global Network 3 expressed difficulties in hiring appropriate personnel with the necessary skills due to limited funding, relying heavily on voluntary activities. Trans-national Network 1 also indicated that they "cannot afford to do different things as it is the structure that [we] can have."

EU Network 3 identified weaknesses in their structure, noting that they are "not strong enough to build formal structures for all the countries." However, they are exploring opportunities "for members outside the executive committee and from specific regions to run their branches, even if they are not in large cities" (National Network 2). Global Network 2 further identified that their structure poses difficulties when "sharing information on a global scale and supporting activities on a national scale."

At the time of the interview, Global Network 2 was in a state of transition regarding its legal structure. Although it lacks a formal legal framework, it strives towards a shared understanding amongst its members. Structural changes were proposed to tackle the lack of funding typically acquired through EU projects. Global Network 2 expressed: "…we need a policy document, a working structure to give something back. It does not need a formal legal structure, but a memorandum of understanding."

Proposed changes included restructuring the network to promote more inclusive voting decisions, potentially supplemented by hiring personnel to manage specific tasks and increase sustainability. "…This knowledge exchange has to be improved, so we can do so by hiring someone" (Global Network 2). The current structure relies heavily on a single coordinator and often involves office relocation based on the location of the board member.

Global Network 3 transitioned from having no legal existence to establishing rules, a constitution, and a formal structure, complete with formal membership and fees. The "scientific community became an elected body from the membership, which was a big change, and it all happened over a relatively short period that changed the nature of the network" (Global Network 3).

Conversely, Global Network 2 expressed its willingness to change its current structure and formalise it to accommodate "…all future members with the aspects and elements they need, including training, conference, dissemination and communication" (Global Network 2). EU Network 2 underwent a name change, intending to broaden its scope, though this change posed challenges for some older network members.

National Network 1 highlighted a change toward a bottom-up approach within their PEN, giving more decision-making power to their community members: "Given this new structure, there was more community involvement and the community was listened to" (National Network 1).

Global Network 4 noted significant growth in the network since its inception in 2004, from one staff member to eight or nine, indicating a broader interest in PES within the broader community.

Subcode: 1.1.4 Effective governance structure

The majority of the networks (for example, Global Network 2 and EU Network 1) approved their current governance structure, indicating the need for a network to be "…an agile organisation.…with clear guidelines to know that we are on the right track" (EU Network 1). Furthermore, EU Network 1 indicated the importance of having "a strategic plan that is translated into an action plan. The action plan in the last two years has been toned down because of the advocacy work".

Global Network 4 also suggested that being part of a larger organisation helps secure funds to pay for the necessary staff: “The governance structure is a good fit in the broader network. It makes sense to be part of public programmes and work across different programmes within the network”.

Global Network 3 indicated that it is better to have a more flexible network, cautioning that a more formal structure might not be suitable for their context: “…but the structure would not work if we were to become a higher income, higher status, more formal network as [there] would [be the] need to change the structures to facilitate [that], and one thing depends on the other”.

National Networks 1 and 2 highlighted the challenge of assessing the effectiveness of their structure, as they lack the ability to modify them.

Subcode: 1.1.5 Topics discussed and documentation of high level-meetings

The topics discussed at high-level meetings vary widely, ranging from operational matters concerning the administration of the PEN to the organisation of conferences and workshops. Citing board meeting minutes, EU Network 1 claims discussions primarily revolve around “government topics and strategic matters.” Similarly, EU Network 2 stated that its agenda includes discussions “about how [they] run the network, the conference, who [they] interact with and who [they] build relationships with.”

Other interviewees highlighted the importance of addressing topics that members need to improve their science communication work. For instance, “what is the latest bad science, controversies such as 5G, COVID-19 or diversity in science” (EU Network 2). National Network 3 mentioned soliciting member suggestions for workshop topics, while EU Network 3 focused on addressing members' PES needs.

Global Network 4’s president emphasised the significance of training, particularly in enhancing science communication efforts:

> Our social media manager engages on Twitter and coaches other scientists and engineers on how to engage on these platforms to both participate in conversations within the community about best practices in PE and support engagement of the various publics that might interested in specific topics. (Global Network 4)

Certain interviewees mentioned that their PENs record their governance meetings, while others do not. Additionally, certain interviewees indicated that they make these documents available to their members. Global Network 2 and Trans-national Network 1 possess such documents, but they are not currently available on their websites.

National Network 2 and Global Network 4 indicated that documents of governance meetings are only available to their members: “Minutes are public just to members, so they would need to sign in to see them" (National Network 2). However, National Network 1 indicated that "board minutes are not publicly available, but maybe they should be."

EU Network 2 indicated their preference to document their meetings using emails, with decisions communicated to their members thereafter. The Annual General Meeting (AGM) is a documented meeting accessible to all individuals, as "the working groups report to the community every year during each AGM…all the meetings are open" (Global Network 1). National Network 2 highlighted the absence of a standardised approach to minute-taking in the past but noted that this issue has now been resolved.

Main category: 1.2 Management and leadership

Sub-code: 1.2.1 Shared values

This main category explored codes related to the various dimensions of management and leadership's shared values, such as trust, commitment, openness, and inclusivity. According to EU Network 1, shared values in the team are seen as catalysts for efficiency: "It makes things go fast—it makes a huge difference for all the other governance structures to develop further" (EU Network 1).

Most networks acknowledge trust as a crucial component of effective leadership within their PEN. Specifically, members report that the management's leadership style relies heavily on trust, stating that "there are different informal indicators that say that we want to keep you and trust you" (EU Network 1). Similarly, Global Network 2 mentioned that management should include "individuals who are trusted and are not working for their personal benefit but for the idea of PE and the networks."

The management and leadership show a strong commitment to enhancing the performance of the PEN for its members. For EU Network 1, members' needs are top priority as "these are basic guidelines, although they are not written. It would be strange to write that our role is to serve members. However, it is good to remind your team that we are there to serve our members." This is similar for Global Network 1 as "…people work together because they are of the same mindset…they want to help students understand and help the environment…irrelevant of whether you are from North America or Africa." EU Network 2 mentioned that despite "having over hundred members in the PEN and having to organise a conference each year, it is already a lot of work for such a small organisation", yet the PEN remains committed to it. However, even though the management is dedicated to the cause – "if they have other commitments with their families, for example, I cannot tell them they have to, of course. That in itself is a weakness" (EU Network 3).

Both National Network 2 and Global Network 2 mentioned openness as an essential value, with Global Network 2 saying that "there is absolute openness with respect to information, and even though not all the information is publicly available, if the information can be shared we do so."

National Network 1 noted that since "[we] are an independent network, with no institutional support, we must have clear and transparent procedures. Otherwise, it will tamper our reputation". Transparent procedures were implemented in the selection process of an award given by National Network 1. They involved an expert committee and selection conducted by an external contractor - a very respected science journalist – who was unaware of the award recipient's identity.

Global Network 4 highlighted that their programs are accessible to all and that "…most of [their] programmes are open to all scientists/engineers regardless of their membership status but of course, we encourage them to join our network if they have taken part…". Global Network 3 stated that their PEN exhibits moderate levels of openness, which can be attributed to the diverse range of countries that are part of their network.

EU Network 1 emphasised the importance of being fair and inclusive to all the members (EU Network 1). Some PENs ensure diversity within their scientific committees, ensuring representation from "different ethnic backgrounds… and we are very conscious of achieving gender and regional balance, and who is visible on the platform at our conferences" (Global Network 3).

Nevertheless, EU Network 1 highlighted challenges in recruiting members or organisations in the East or South-East of Europe: "… because we work at EU level, being able to say we can cover a lot of countries is useful." EU Network 3 observed a shift from a formal to an informal atmosphere over time, stating that "in former days, it was a bunch of older guys meeting in a friendly atmosphere. Now it includes a lot of young people as well, a lot of enthusiasm."

EU Network 1 wanted to be more inclusive in the resources available to members, such as "the magazine, it could have been just for members as they pay a fee. However, we feel that we can use this magazine as an advocacy tool and everything that we do, so we made it available to everybody useful with our governments." Similarly, EU Network 2 opened the doors of their conference "to non-members as well, making it more interesting (not just sixty/seventy people) but more than two hundred people attending."

PENs also value gathering feedback from their members - "… by asking how we can make our PEN activities more inclusive" (EU Network 1). Global Network 4 also use this approach and finds that it has been "moderately effective…asking people what they would like to know and when."

The PEN's remit might also inadvertently exclude certain professions, like journalists, from joining the network. This approach is seen as outdated "…and it is not the way in the future" (National Network 1).

Sub-code: 1.2.2 Effective management & leadership

The effectiveness of PENs is demonstrated through their longevity and accomplishments. Global Network 1 stated that the PEN "has evolved over the past 25 years, which is a good thing." For instance, Global Network 2, showing how long the PEN has survived, claims that their "…leadership style is very effective. It kept us moving forward, we got recognition, shared our expertise, and we now have the 9th conference in 20 years."

The EU Network 1 has effectively established a credible and equitable framework by devising transparent guidelines and protocols. As an illustration, the network operates as an umbrella for third parties that participate in an EU project, admitting some members through an open call. Prior to this approach, the network relied heavily on informal networks, where projects were often allocated based on personal relationships.

The efficiency of the network's leadership is dependent on the prescribed roles tailored to the strengths of its members. For instance, "…The one before me had a marketing background so she rebranded the website and made it look really nice. She made it quite tailored to practitioners rather than researchers and then another president, he was a researcher, made it very academic…" (National Network 2). However, problems arise when the head of the PEN exhibits a lack of dedication to the organisation as a result of other personal obligations, as noted by (Trans-national Network 1: "…Our PEN last year was non-existent for me. The leadership of the PEN was not in the forefront. This is one of our weaknesses".

Board member selection processes vary across PENs, ranging from democratic voting systems to informal agreements. EU Network 3's interviewee stated that they "have an executive bureau, including the president, the vice president, treasurer, and the secretary. We create a budget every year and present it to the steering committee." EU Network 1 noted that "there is a different style, and I adapt to their style. It takes a couple of months to get used to their style" (EU Network 1). The structure of National Network 1 is quite hierarchical, which poses some challenges as they "want to make more memorable connections. There are only 2 people on the same board within the same city, so we have to coordinate and discuss things" (National Network 1). Global Network 4's interviewee pointed out that their current system is more democratic as "before 2013, it was less of a democratic process, the input was less because of the structure of the office of our hosting organisation." At the higher level, the following interviewee indicated that "it is not a democratic process at the moment; we do not have votes regarding the network. It is an informal agreement; we all work on the same idea. People take different responsibilities" (Global Network 2).

While "all the work is voluntary, they are all in paid positions, so they have the opportunity to spend some time for the cause that the PEN works towards" (Global Network 2). However, EU network 3, noted that it is easier to fill in those roles that are not so difficult to complete: "It is more or less the same roles, the pleasant tasks are easily appointed". The treasurer oversees finances within the PEN, which may be audited externally through a paid position. However, the president is always informed of the network's financial status (Global Network 3; National Network 2).

Challenges such as insufficient membership, financial constraints and cultural differences require adaptive leadership and collaborative problem-solving. In certain PENs, extra nodes that coordinate with top management in running the network may be needed. For example, "[there are] subgroups in place to take care of membership social media, finance, etc." (Global Network 3). Committees are occasionally created to manage temporary roles, such as "the program committee [which] is responsible for the content and structure of the conference" (Global Network 3).

Within a network, individuals perform minor roles that handle various platforms in "communication such as "social media, and get scientists involved. Again, there is no one model for how it is implemented within each country" (Global Network 1).

EU Network 1 emphasised that addressing tension is integral to serving members or advancing the field, which they consider as part of their remit as a PEN. Additionally, team-building activities, such as having lunch together, contribute to network effectiveness. Trust is a key factor when it comes to building relationships between people. "This year more and more people attended the conference, and this face-to-face contact is much better than virtual. It also increases the connections through networks and solidifies recommendations that we recommend as well" (National Network 1).

The ability to tackle challenges by devising individualised solutions is key, as the PEN states that it

> …is involved in ideas of social responsibility and accountability and transparency and democracy but does not have any worked-out policy position precisely because we are a global organisation. It would be impossible to come up with one size fits all. (Global Network 3)

A notable challenge that leadership successfully tackled was the issue of insufficient membership in another country. "So we made a delegation including myself, and we went to some of these Universities and offered content on how to engage in social media to create ambassadors for our universities. There were sixty people present, coming from 12 different universities" (EU Network 3).

Another challenge is the "big uncertainty with the conference. We do not know how many people are going to attend" (EU Network 1). Another issue related to the conference's organisation was a "considerable loss and was threatening the reserves for such things" (EU Network 3).

The financial status of PEN was also affected by "COVID-19 [as] it is not going to be as good as we think it is going to be with memberships, sponsorships…" (National Network 2). National Network 1 emphasised the importance of "being careful in writing partnership agreements, funding, and other forms of partnership, often because of that lack of business culture, they have different ideas of what our popularisation is going to be."

Other challenges that management had to tackle were the different cultural expectations of the various countries included in their PEN “for example when we developed a new corporate identity, in the south, they wanted to make it clear that you're an official institution…In the north, they say keep it simple, we do it business-like” (EU Network 3).

Continuous challenges for management include marketing their PEN as they “would need a promotional budget in millions to reach everybody who might need to be or deserve to be reached” (Global Network 3). Furthermore, the Global Network 3’s representative stated that have “attempted to have a participation restyle encouraging people to express their opinions and join in decision-making…so I would like to provide cohesive leadership.” Management also struggled with a lack of coordination from their members on using the PEN’s mailing list, resulting in duplicating certain email threads (Global Network 3).

Sub-code: 1.2.3 Funding and distribution of funds

Effective project management and financial stability are crucial for PEN management, as highlighted by EU Network 1. However, the voluntary nature of their role presents challenges, as noted by EU Network 2: 'Increasing the director's working hours may alleviate this difficulty.'

Another challenge that management tackles is ensuring financial stability from various funding streams (EU Network 2). The PEN of Global Network 3 is currently in survival mode due to insufficient funding, resulting in limited potential for growth as a PEN, according to their representative.

The sustainability of a network relies not only on the amount of funding it receives but also on the stability of its funding sources. PENs mentioned that “funding comes mainly from membership fees and payment from conferences” (National Network 3).

While National Network 2 emphasised that their PEN “is completely non-profit”, National network 3 indicated that “in most years, it is a profitable conference, ensuring we remain within the safety margin. In the last four years, we have seen positive returns from these avenues.” However, this was not the case for EU Network 2: “Our PEN does not get a lot out of the conference” and Global Network 3 claiming that their main source of income is a “very modest membership fee.”

EU Networks 1 and 2, and Global Network 2 rely heavily on EU projects for funding, acknowledging that “…this kind of success we had through EU support…” (Global Network 2), which plays a crucial role in sustaining the PEN.

A notable issue raised pertained to the cessation of funding streams, specifically Science with and for Society (SwafS), which were anticipated to be unavailable during the interview period.

> The EC office we are 100% funded by our own resources so some comes from membership fees (1/3), depending on the year, business bistro (conference (1/3) and one-third from the EU projects… We do not receive funding from governments, so we are self-sustainable and rely on our resources. (EU Network 1)

EU Network 2 highlighted the challenges in obtaining funding, stating that "it was far easier to get funding for activities from the network itself and for networking activities, for example, doing joint activities in the science festivals… and I think the Commission's funding strategy has not really improved, more on the contrary."

Trans-national Network 1 expressed disappointment with the availability of funds. Researchers with different programs in Europe can apply for EU funds, but there are no Latin American funds available for their PEN. Other sources of funding include donations, described as "…basic stuff, which is indirect support" (Global Network 2). National Network 1 mentioned funds from "private funders, grants from foundations, state funded foundations and these would be project-based, conference or award then we work on project based." Substantial funding "from philanthropic organisations, individual foundations and corporate donors" was mentioned by Global Network 4.

Global Network 1 pointed out that there are some national networks that acquire funding through government sources: "[Government agency] is the primary funder. It also funds the app and this is from a different funding stream. So there are two funding streams within [this agency]". Additionally, it was noted that "[they] do not give any type of funding to any country coordinator. [They] support, them through other means, letters of support, etc, but not through funds" (Global Network 1).

The interviewees provided insights into how their respective PENs maintain a positive balance at the end of the fiscal year. For instance, EU Network 1 mentioned that they "do the budgets and the board approves the budget at the AGM each year." Similarly, other PENs such as EU Network 3 reported budget approval at the AGM.

PENs prioritise financial planning to avoid a negative balance, often projecting three years ahead. This practice is echoed by PENs like Global Network 2 and Global Network 3. Budget prioritisation typically starts with the most expensive activities and items, such as website maintenance and conference expenses (EU Network 1).

National Network 2 highlighted that - "there was no indication from previous presidents about not having a negative balance, so my first year, I was keeping my fingers crossed". Additionally, due to a centralised system: "…even for network nights where I buy the food, I have to authorise my own payments to get refunded" (National Network 2).

While the role of treasurer is not always a paid position, some PENs opt to professionalise the position by providing payment for their time and work, as exemplified by EU Network 3. Funds acquired are often allocated to paying the team to organise events, services, and conferences (EU Network 1).

The distribution of funds depends on the remit of the specific PEN. For instance, National Network 1 said that "funds are mostly dedicated to networking and education." For EU Network 3, some of the funds are distributed towards creating workshops or supporting member countries to hold workshops and activities in their respective country where "essentially the membership fees go back to activities that members make use of." Global Network 4 claimed that they "charge for workshops, so the money goes into that specific programme."

As part of the efforts to support PEN members, initiatives like collaborative grants are launched, as declared by EU Network 1. Additionally, PEN leadership proactively considers scenarios where the network may no longer be sustainable and may need to be liquidated (EU Network 1).

Trans-national Network 1 mentioned that they encourage their workplaces to cover some of the conference expenses for the board members to attend. Meanwhile, their PEN would take care of other logistical expenses. However, Trans-national Network 1 also mentioned that they face difficulties in organising programs with other countries due to a lack of funds.

Sub-code: 1.2.12 Evaluate network

This sub-code focused on PEN's self-evaluation at the network and community levels. This includes an assessment of the effectiveness and sustainability of PEN's management and an evaluation of whether the network's aims and missions are being achieved. Additionally, the satisfaction of PEN members with the services provided by the network was also examined.

Some PENs indicated that they conduct surveys to evaluate whether their members are satisfied with what the PEN offers - "we understand what works and what does not…It is also very transparent. We want to support our science communicators to produce high-quality work as well" (National Network 2). This was also echoed by Global Network 1.

Global Network 4 stated that they evaluate their activities to see "how their perception of their abilities and role changed due to participating in training and PE activities, like family science days." Furthermore, various PENs evaluate specific activities they offer - such as workshops or conferences "so we can assess what is the best from the conference and what we need to improve on: length of the sessions, format, participation of the session or different sessions, different formats of poster sessions etc" (National Network 3).

In addition to soliciting feedback from members, the evaluation process serves as a valuable tool for guiding the PEN's strategic direction: "It would be interesting to look more forward. What is the perspective of the network members? How would they like to see the situation improved?" (EU Network 2).

PENs discussed the process of evaluating programs and the data they obtain, however, they failed to provide in-depth information on the methodology of data capture. EU Network 2 expressed that "it could be much better in terms of evaluation and monitoring." EU Network 1's representative discussed the struggles to "get information from the members and sometimes to the members. Surveys do not really work with our members; we are not their priority stakeholder as we do not provide money for them."

Main category 1.3 Policies

In this context policies can be laws, regulations or procedures that the PEN or their members use or are affected by in conducting science communication.

Sub-code: 1.3.1 Institutional and EU policies

Most members engaged in PENs are affiliated with university institutions or science centres. Global Network 2 emphasised the significance of Universities' policies, stating, "Wherever science shops exist, they do so within the universities that support them." Other institutional policies encompass "policies of science centres, government science awareness campaigns, professional societies or universities that financially support staff members taking part in our conferences" (Global Network 3).

The interviewee from Global Network 1 highlighted the necessity to implement regulations concerning privacy, particularly related to government agencies due to federal funding. EU Network 2 commented on the influence of European Network 1 stating they "have an office in Brussels and a few people working for them…and total different possibilities to change the policies in Brussels." EU Network 1 mentioned their direct engagement at the EU level but not with national governments.

Despite the freedom to involve everyone, EU Network 2 noted that resource constraints limit collaborations, particularly in covering travel costs. Funding calls governed by policies like SwafS in Horizon 2020 (EU Network 1), exclude countries outside the EU (Trans-national Network 1). The EU has implemented a range of policies to support different programmes, and Global Network 2's representative feels that they "have a responsibility as they benefited from the processes and support, so we need to give back something similar to a policy document."

Various European policies have been implemented to protect data, including the General data protection regulation (GDPR) policies. Global Network 3 noted that GDPR "is relevant to the EU area and not outside since we are a global organisation," while EU Network 1's representative lamented that it has "…has hindered our communication rather than our participation."

Sub-code: 1.3.2 Internal policies

Several networks indicated a lack of fixed policies within their PENs. National Network noted that they "… do not have much government regulation of science communication, no dedicated policies or any kind of laws. It is only indirect through issues of science and society." This suggests a flexible structure.

Transnational Network 1 acknowledged limited policies or regulations within their PEN. National Network 1 revealed that their policies are not documented but are instead considered " codes of practice rather than policy documents." Similarly, EU Network 1 noted that "sometimes you can write these things but then not practice them. If it is really shared, you do not need to write it." National Network 2 indicated that "the problem is there is no behind-the-scenes/handover official documents," especially when there is a change in management.

Global Network 2 mentioned internal policies, such as those concerning gender balance, and expressed a preference to hire men due to gender imbalances.

Sub-code: 1.3.3 Policies that hinder/encourage participation in science communication and the PEN

PENs discussed the potential for developing a framework for inclusivity and professionalising science communication by creating – "…some guidelines for good science communication, which also reflects ethical issues for e.g. gender and so on" (EU Network 2). National Network 2 highlighted efforts to integrate inclusivity and accessibility into their strategic plan.

Trans-national Network 1 noted political instability in Latin American countries hindering science engagement, despite efforts like new laws in Chile and the establishment of a Ministry for Science and Technology in Colombia.

Factors impeding participation in scientific networks can stem from institutional policies or the political climate. Scientists might face limitations while engaging with members of Congress or staff during government-related visits due to following protocols for the agency that employs them (Global Network 4).

Other limiting factors are "when we do training about how to engage with policymakers or subjects revolving around policies topics, [scientists] may feel that the regulations within their home agency limit the ways how they might put those best practices to good use" (Global Network 4).

Challenges limiting participation "…to become a member, the administrative structure has to sign a membership agreement, which proves to be more difficult" (Global Network 2). Some networks have implemented tired fees to promote inclusivity (National Network 3), while others struggle with administrative hurdles (EU Network 1). Ultimately, the sustainability of a network depends on resource availability than legal frameworks (EU Network 2).

6.2 Theme 2: Community level – Relationships

Table 6.2 shows the main themes for sub-codes related to the community level and the relationships between the stakeholders.

Main category: 2.1 Values of the network

Table 6.2:

Main themes and sub-codes of Theme 2

Theme 2: Community level: Relationships		
Main Categories	**Sub-codes**	**Description**
2.1 Values of the network	2.1.1 Community learning and engagement support	Refers to opportunities available for PEN members to access knowledge and learning. Engagement support can be embryonic, developing, gripping or embedded within the PEN[21]
	2.1.2 Shared values of the PEN members	Refers to the shared values of the PEN members and whether they practise inclusion of underrepresented groups.
	2.1.3 Accessibility of the PEN to members and non-members	Refers to whether documents and research are available to both members and non-members.
2.2 Membership	2.2.1 Membership fees	Refers to the purpose and function of membership fees and how they vary across the PENs.
	2.2.2 Network's membership size and relevance	Refers to the benefits and/or challenges of the PEN's membership size.
	2.2.3 Supports good relationships between members and stakeholders	Refers to the PENs' ability to support healthy relationships among its members.
2.3 Stakeholder diversity	2.3.1 Academia	Refers to stakeholders' knowledge creation in education, at higher educational entities and research institutions and centres.
	2.3.2 University	Refers to stakeholders working at Universities, including those working in research positions, laboratories and administration.
	2.3.3 NGO's	Refers to NGOs that involve citizens with science as stakeholders.
	2.3.4 Government	Refers to ministries and departments within governmental entities as stakeholders.
	2.3.5 Partners in projects	Refers to partners in EU projects as stakeholders.
	2.3.6 Educators	Refers to educators working in compulsory education as stakeholders.

[21] The engagement support is categorised based on the EDGE tool model, as applied by the National Co-ordinating Centre for Public Engagement (NCCPE). The support can be embryonic, developing, gripping, or embedded within the network.

	2.3.7 Science centres and museums	Refers to science communication practitioners working in interactive science centres and museums.
	2.3.8 Researchers/Scientists	Refers to researchers and scientists as PEN members and stakeholders.
	2.3.9 Other networks	Refers to PENs' involvement with other networks as stakeholders.
	2.3.10 Journalists	Refers to journalists as stakeholders and PEN members.
	2.3.11 Citizen scientists	Refers to citizen scientists as stakeholders and/or PEN members.
	2.3.12 Other	Refers to other infrequent mentions of stakeholders not mentioned in the list above.
	2.3.13 Stakeholder experiences	Refers to experiences related to reputation and resources that impact the PEN.

Sub-code: 2.1.1 Community learning and engagement support

This section focuses on exchanging knowledge and information about RRI, science communication, societal issues, and PES. It emphasises the importance of learning from the experiences of other community members. This sub-code evaluates the opportunities available for members to access knowledge and learning. The engagement support is categorised based on the EDGE tool model, as applied by the National Co-ordinating Centre for Public Engagement (NCCPE). The support can be embryonic, developing, gripping, or embedded within the network.

Limited access to professional development opportunities for members to enhance their skills and knowledge of PE exists in the *embryonic* stage. Furthermore, there is a lack of effort to coordinate PE activities or network expertise and learning throughout the PEN.

The issues identified by the PENs were related to funding, "especially around countries with very little funding. How do we encourage them? What implementation models do countries have? We cannot tell people what to do, but we do ask people to share their implementation models" (Global Network 1). Trans-national Network 1 mentioned that "not a lot of countries in Latin America invest in research. Research is not a big topic in Latin America, and PES is even less…."

If the support is *developing*, there exists some possibility for individuals to obtain PES training and professional development within the PEN. However, there is a lack of organised and structured assistance in this area. Global Network 2 stated that their members and board members "meet at other conferences concerning PES…There is an informal exchange and then our members communicate these into the network."

During their interview, EU Network 2 mentioned their focus on developing an online platform "as a resource for science engagement in Europe, where you can bring together stakeholders for good science communication or values of RRI, etc... about the implications of our work."

National Network 2 indicated they "support good science communication and help with communicating science, but we do not have anything to state concerning our country." Trans-national Network 1 reported that due to limited funding, they have had to adopt innovative approaches to PES among citizens by having "science engagement programs that are translated into different languages. These things have happened in Latin America for quite some time. Some topics that are now important in other regions are those in which we have a lot of experience" (Trans-national Network 1).

The support is *gripping* if, within the PEN, formal avenues exist for members to obtain professional development and training in PES. Oversight and coordination of PES have been formally allocated (for example, to a working group or committee), but there is minimal support and resources to invest in the activity.

Global Network 2 and Global Network 4 prioritise knowledge-sharing, through newsletters, fellowship programmes and coaching. This is echoed by Global Network 3, which states that "the aim is to encourage, support and facilitate people on science communication, in various roles across the world."

Being connected to other PENs and infrastructures, such as "other organisations in Europe to connect our activities on a European level better and learn from each other" (EU Network 2), gives better opportunities for their members. Similarly, Global Network 3 hopes to "strengthen the roots of such communication infrastructures as networks in different regions in the world." Global Network 4 mentioned that their PEN acted as a catalyst, and a "civic science initiative primarily started by our PEN now involves several philanthropic organisations that are interested in how to support scientists in society to do PE."

Assistance in media coordination is another area of collaboration with academic institutions and research centres (National Network 1). Networking is critical if resources are lacking, so they "set up an engagement platform for science engagement and asked people from outside the network to work with us in the working group" (EU Network 2).

The conference, as highlighted by National Network 3, serves as a structured platform for PEN members to enhance their professional credentials by presenting or participating in workshops. As the sole science communication conference in the country, it facilitates knowledge exchange across diverse science communication domains, fostering networking and collaboration. This underscores the professional legitimacy of participants within their own organisation (National Network 3).

Offering support to members within the PENs included identifying "specific needs for a specific island. One thing the [members] mentioned was the lack of formation. Many of them learn by doing, so we designed specific workshops to address that" (National Network 3). Another approach is holding webinars whereby Italians had the opportunity to "talk to people and exchange experiences how it has been with quarantine and lock-down during COVID-19" (EU Network 3).

Global Network 1 indicated that "the kind of support we can provide is limited, which tends to be supporting the implementation within the country." Additionally, Global Network 4 added that the lack of human resources is taxing on the PEN's staff: "As more people participate in our programmes, we have more requests from people to continue with that engagement." Another *gripping* approach to community involvement is the "rise to publications in this as due to an increase in PE, making science shops visible" (Global Network 2).

In the *embedding* mode, the PEN has implemented a strategic plan to facilitate coordination, oversight, and embedding of PES. This plan is supported by resources that enable members to access professional development, training, and informal learning opportunities that are key to enhancing their skills and engagement knowledge. Additionally, established networks are recognised and supported to improve this objective further.

PENs indicated they hold/organise various workshops and offer support by "paying for everything, and then the host university does catering and pays for the speaker…" (EU Network 3). Additionally, the structure is provided through "organising committees... so, we have relations outside the network but mainly with the universities involved and not so much with outside parties like industry or government. We do not do any lobbying or projects for the EU" (EU Network 3).

Further examples of the conference as an embedded way of organising training and engagement support were given, such as a "website to facilitate sharing resources [was created]…and members who assist in voicing citizens' requests to policy-makers" (EU Network 1).

To support the PEN, their "workshop programmes are a specific revenue stream where organisations buy a workshop that supports the staff who develop and deliver them" (Global Network 4). Trans-national Network 1 wanted "to support the research or work in different things by publishing a book." Other activities to support Global Network 4's members include fellowship and award programmes "that recognise early and non-early career scientists for PE, although we only have one award winner."

Sub-code: 2.1.2 Shared values of the PEN members

PENs prioritise serving their members and practising inclusion of underrepresented groups, such as indigenous groups, underserved groups, women in science, and others within the PEN.

Global Network 2 emphasised that "being inclusive, fair to all the members [should be a] priority and a service to members." Similarly, EU Network 3 stated, "that we are definitely not exclusive in any way, but we do not make any special effort to include different backgrounds/perspectives."

The representation of women in science was discussed among the representatives from PENs. National Network 3 mentioned "a lack of female representation in engineering, but overall, it is not that bad." Global Network 4 echoed this sentiment, stating that "there are more men scientists in research than those doing PES, but this is changing.” Additionally, National Network 3 indicated that the gender imbalance is not as concerned as in “Portugal… when it comes to research and innovation in science and technology even in women, some are directed by women so in comparison to other countries we are doing well.”

Global Network 4 aims to empower women to pursue STEM careers by reaching out “through programmes such as STEM ambassadors, and there are 125 women in various STEM careers who are already reaching out to connect women.” While it was indicated that women researchers in specific science fields, such as engineering, are scarce, women science communication practitioners are abundant – “and the number of men is definitely underrepresented. So we have 35 people working with only 10 being men” (Global Network 2). This sentiment is echoed by PENs across the globe - Global Network 3, National Network 1, National Network 2, and Trans-national Network 1.

National Network 1 indicated that gender issues are embedded in society and that the problem lies “more outside the network rather than within. There is a glass ceiling in the lower levels that is dependent on the field of science, as you find many women doing their doctoral studies. Furthermore, there are many **males in top management**.”

Science communicators are often perceived as service providers rather than experts in the field: “A typical science communicator is a lady, so you are not seen as an expert but as a service that you are going to provide” (National Network 1). National Network 2 elucidated that “it could just be the nature of the work. There is a stereotype that communication is for women - which is rubbish, of course.” While science communication practitioners tend to be female - “if you were to ask people to name a scientist or science communication superstars you are much more likely to hear Carl Sagan, Bill Nye, Neils deGrasse Tyson than you are to hear about Katherine Hayhoe, even though both genders are superstars in their field” (Global Network 4). Furthermore, Global Network 4 addressed that “PE needs to be included as part of the promotion for the 10-year criteria, rather than just recognising [scientists] for doing something on the side…there are these broader conversations in society about the extra load that women carry that is not recognised in their formal work plan.”

There are several underserved communities within science communication. Global Network 3 argued that “science communication reproduces power relations and hierarchical relations in society...” However, specific causes outside of the PEN tackle issues in the underrepresentation of certain groups in society and underserved groups, such as “people with visual and hearing disabilities…working to improve the experience for them” (Global Network 3).

While certain underrepresented groups are being encouraged to participate within the PEN, there are still underrepresented groups within EU Network 3 – “…if you see the group photo that we take every year, I do not see any coloured people, disabled people. We have diversity in the sense of gender, the LGBT community, but not within other sectors.”

Inclusivity has always been important to Latin American countries as the situation has been quite dire for the past 20 years, although "you see the difficulties for the US to engage different audiences and vulnerability" (Trans-national Network 1).

Furthermore, EU Network 2 identified the challenge: "If you want to work with diverse groups of underserved audiences, you need 4/5 years to get the trust of the groups and get them involved and get meaningful projects." Nonetheless, the delegate from the Trans-national Network 1 provided several illustrations showcasing the incorporation of diverse marginalised groups "through our members. For example, in Colombia, they have a programme in the planetarium for blind people. In Brazil, there are diverse programmes for people from vulnerable groups like favelas or jails."

Some other examples from Trans-national Network 1 include "translating science engagement books to at least two native languages to spread science programmes to children of native villages." Another example of empowering people within Global Network 2's PEN was "a project in the botanical gardens, to reach out to Roma people…even though it is not directly related to our PEN."

Various PENs are pursuing different initiatives within their community, with some focusing on " bringing a group of people together to create a diversity, equity and inclusion statement and plan for the programme" (Global Network 2).

The representative from National Network 2 identified several examples that were implemented within their conference – "We had people from different backgrounds: a person with autism, transgender, Maori, somebody who was gay, someone in a wheelchair, Chinese, New Zealander and others." National Network 2 also worked on making the

> "place accessible to different people, not just for wheelchairs, but for people with neurodiverse conditions such as Aspergers, to have a quiet place. We also had these little badges to show that if you like to talk, you put green, while a red badge means that they do not want to talk."

National Network 2 further revealed their successful efforts in affecting a global PEN to enhance their conference's inclusivity by "suggesting to the president at the time that we wanted to influence and wanted to be more inclusive."

As part of its efforts, Global Network 3 has implemented a measure to lower the cost of conference fees for members hailing from various countries such as Germany and Ghana… "We are involved in ideas of social responsibility and accountability, transparency and democracy." Other initiatives ensure "an equal number of men and women in the panels in conferences, and it is also written in the [project] calls" (EU Network 1).

All the PENs in this study consider networking an essential asset for the organisation. As a result, they actively engage in various initiatives to promote networking opportunities and ensure diversity and inclusivity.

The benefits of networking include “opportunities and events where our members can meet and share” (EU Network 1). Furthermore, the aim is to “connect with people from different countries. Generally, its basis in friendships that help to better things” (Trans-national Network 1).

EU Network 3 mentioned that their PEN is “a close community. We call it networking with friends…where people can meet to share good practices.” Networks tend to provide a platform for discussion, for example, “networking nights, and we had increased these (had COVID-19 not happened, we would have done six)” (National Network 2).

Trans-national Network 1 mentioned that members form a long-term relationship if ideas come to fruition. Even if members work together on short-term projects, “some of the partnerships might sustain and be partners in future cooperation as well” (EU Network 2).

Although PENs generally aim “to help people come together on projects and collaborate…it may sometimes not work well” (Global Network 2). Physical conferences remain the primary venue for formal networking, with organisers facilitating informal activities like dinners and social events: “…you get to know people informally, so you are talking over a glass of wine” (National Network 2). Global Network 2 highlighted that conferences are a way to “talk to people at a high level.”

For global and national networks, collaborating with other networks and organisations can benefit their members and include various people. Networking can also occur by “going out to other conferences that do not know of our PEN” (Global Network 2). Networking facilitates the exchange of information and promotes awareness of ongoing research activities, thereby enhancing collaborations and partnerships. (Trans-national Network 1).

Sub-code: 2.1.3 Accessibility of the PEN to members and non-members

This section delves into the PEN's accessibility to both members and non-members. Specifically, it examines the extent to which documents and research are openly available to members through their websites and other communication channels.

Information tends to be shared on the PEN’s website and social media channels. While “not all the information is publicly available, we share what is needed…It is open to all and supports the idea of bottom-up research and access to research resources” (Global Network 2). Similarly, National Network 1 mentioned a “Facebook group for public matters and a website about the projects to inform people.”

Other communication channels include “livestreaming the keynote speaker, as it is feasible. But with ten sessions happening simultaneously at the conference, recording everything is difficult. Topics of past conferences can be found on the website" (EU Network 1). Global Network 4 mentioned that some of their programmes' meetings are available on YouTube.

A distinction is made between varying levels of transparency within the PEN, depending on whether they are management or members, with management having higher levels of transparency and the "two and a half thousand subscribers on our mailing list see a little bit of what we are doing but do not care how it is done" (Global Network 3).

Global Network 1 mentioned that they have a "database that provides open source data so anyone can access it, and it was purposely done that way. You can enter data as a citizen scientist or a trained teacher."

Main category: 2.2 Membership

Sub-code: 2.2.1 Membership fees

Every PEN network has a fee system for requesting payments from its members, claiming that they are "very modest" (Global Network 3) and "very small" (National Network 1) except for Global Network 2, which states that "there are no membership fees." The purpose and function of membership fees vary across different networks.

According to Trans-national Network 1, their sole revenue stream "is from institutional-based membership fees. Although the fees are quite low, we have many problems collecting money from our members." PENs run into several issues when their members "say we will have delays, so we have become more strict. This is also true in many organisations; the governments are now more worried about money laundering, and everyone is much more careful" (EU Network 1).

Membership fees are reinvested "to define services for the members" (EU Network 1). Similarly, EU Network 3 mentioned that the fees "go back to activities that members use."

The COVID-19 pandemic has impacted PEN membership, and "membership fees are not coming in as always. Since the physical conference will not happen this year, we have a decrease in membership and membership fees. On the other hand, the costs are lower…" (EU Network 3). Similarly, Trans-National Network 1 reiterated that "this pandemic could be challenging for many people. Latin America is always in a difficult economic situation."

According to the National Network 3, members who pay their membership fees are entitled to a variety of benefits, including reduced costs for workshops and special pricing for students. Other initiatives that encourage membership are decreased fees for conferences (EU Network 1). To further increase accessibility, National Network 3 added institutional membership fees "not just individuals affiliated to the network…so that the people that work in this institution will also have a reduced fee for the conference."

Registration is an online system "connected with the accounting system, so a drop-down menu with your organisation's name will appear upon payment. This has helped speed up the payment system a lot. I have someone who sends reminders, phones, emails…membership payment now is at 94%" (EU Network 1). Similarly, EU Network 2 keeps track "by sending out invoices. There is a bookkeeping system, and the director takes care of this with the help of an online system."

EU Network 1 claimed that "the price of the event hinders the participation of some participants. However, without a fee, we will not exist…We try to achieve a balance between sustainability and accessibility. Prices are reduced for members to assist" (EU Network 1).

In contrast, it is worth noting that Trans-national Network 1 does not rely on an automated system for membership management. The treasurer and the president assume responsibility for monitoring membership. Similarly, National Network 2 does not employ an online system for this purpose; rather, a designated individual sends an annual email to inquire about participation in the AGM following payment.

EU Network 3 and Global Network 4 utilise different approaches to fee collection. EU Network 3 relies on its national representatives to gather membership fees via its national network or universities, while Global Network 4, as part of a larger network, has a dedicated department for this purpose.

Sub-code: 2.2.2 Network's membership size and relevance

Most PENs have reported that having a larger membership base brings significant benefits: "The bigger the network is, the better, because then you have more people, generates more interest to encourage more people to join" (National Network 1). Despite this, "growth is not endless, so we have estimated how many groups we can have" (National Network 1).

National Network 3's interviewee noted that "the benefit is to have the most number of members involved in our network, not just for the financial aspect…but also for the workshops and conferences." Similarly, EU Network 3 stated that more members make "outreach better as what we have to offer is more widespread…which also includes more junior-level members." Global Network 3 stated they "could easily handle two or three times as many members." Another national PEN mentioned that "it does not make much of a difference just because our country's population is small anyway" (National Network 2).

Having more members has "no impact on the overall effectiveness of the network management at the moment" (Global Network 2). Some of EU Network 3's took on an elitist view as while the "PEN has grown, some members say that it is about quality and not quantity and should not do too many activities that attract a massive young public as we just want to talk with the old guys." Another issue identified was "maintaining the number of members and increasing funding for the annual conferences..." (National Network 3).

A country's financial condition significantly impacts the number of active members, as some members may not be able to bear the cost of their membership fee (Trans-national Network 1). A couple of concerns arise with the growth in membership of the PEN. One is the absence of customisation within the network – “More members make you stronger but more anonymous…If conferences grow bigger, there's a limitation that you do not know the people” (EU Network 2).

A benefit of having a small membership is that “you get to know quite quickly, but on the other hand, it becomes an echo chamber, and it is good to get out of that… We try to counteract that by getting people not from our country to get fresh content and not just what they think is best practice” (National Network 2).

It is desirable to have members from a wide range of countries represented. However, Global Network 3’s membership “is spread quite thinly across the globe. In any given country, there might be two or three or four members or maybe ten or 12 in some cases. We could easily handle two or three times as many members.”

PEN’s management discussed various strategies to attract new members to the network. The representative from Trans-national Network 1 compared attracting network members to “a wave…it is sometimes more or less effective. It was higher a few years ago, and now we are a little down because the last two years were very tough.” Similarly, Global Network 1 “depends on the countries and their partners to attract more members.”

National Network 1 uses award ceremonies, to encourage individuals to submit their communication work for evaluation. Some additional examples of efforts to expand the network include "hosting conferences that showcase the vitality of our community...We also hope that our upcoming website and platform will draw in new members" (EU Network 2). Similarly, Global Network 2 holds a biennial conference that is gaining popularity, with 300-350 attendees and newcomers bringing fresh perspectives. Further initiatives include "a blog where members can exchange ideas and share success stories related to PE. These avenues, along with opportunities for fellowships and community involvement, serve to attract new members and build a vibrant scientific community focused on PE" (Global Network 4).

EU Network 1's representative emphasised that they “attract [new members] by providing good services…But attracting and keeping them are two different things.” Other strategies include using national representatives to encourage new members to join (EU Network 3, Trans-national Network 1). However, they mentioned that if the national coordinator retires, they “have to pray that the successor is good” (EU Network 3). Success depends on the efforts of these national coordinators, and having one who is not committed “could decrease [the membership] by 50% or more in that country” (EU Network 3).

The tactics employed by the Global Network 3 included requesting the existing members to bring in new members. Moreover, the organisation attempted to devise membership benefits that could appeal to a larger audience, albeit in vain. National Network 2 has identified the power of word-of-mouth as a crucial factor in attracting new members. Despite "resources for marketing being quite limited. We tried to attract new members from new projects as people can see that we are a good network" (EU Network 2).

Global Network 1 has developed an app "to enter data linking it to citizen science acting as influencers." One strategy that has been effective in attracting new members is organising lectures and presentations, where the PEN showcases the methodologies that they use (Global Network 2). As mentioned by Global Network 2, this approach has been successful and is being implemented by several of our colleagues as well, with around 5-6 events being held annually. Through such initiatives, PENs can effectively demonstrate their ability to effect change and promote collaboration within their respective fields.

All the PENs discussed the role of digital technology and social media in changing the landscape of communication with their members, which is crucial in staying a relevant PEN. Trans-national Network 1 started with "letters or traditional mail…now we do not send anything through post." Global Network 1's interviewee mentioned that back "in 1995, email was used when the internet era started, and even people did not know how to use that. We have evolved to social media." Similarly, this PEN now "use Facebook as our principal platform" (Trans-national Network 1) and Twitter (Global Network 3). Global Network 3's main communication is "through email, as when we tried various other platforms, it was with limited success."

Interviewees expressed the importance of having a variety of communication channels to stay relevant as "social media makes it easier to communicate back and forth. Email is still used as it involves different age groups" (Global Network 1). Global Network 4 stated that "social media has allowed us access to people we may not have had access to before." Furthermore, Global Network 2's representative mentioned that "social media tools [tend] to be used by younger people…while I follow Instagram but do not contribute or create videos for YouTube." According to the Global Network 4, social media serves as a platform for exchanging information, seeking advice, and celebrating the achievements of their members. It also allows them to stay up-to-date with the latest developments in the sci-com community.

Digital communication has allowed members "to improve [their] level of participation" (National Network 1). EU Network 1 has transitioned "a printed magazine, to a digital [format]. This allows us to consolidate all the communication tools in one channel." Similarly, Global Network 2 indicated that it has "a monthly newsletter. Every quarter, I send out a video-taped letter to the community." EU Network 1 has indicated that sending an email newsletter is most efficient as "members do not like to receive a lot of emails. Having a system to target their interests would be really expensive to develop…"

Mailing lists have been a valuable tool for communication within and outside PENs' membership. However, it is worth noting that there are distinct mailing lists for members and non-members, with the latter attracting a significant number of followers, according to Global Network 3.

Global Network 4 mentioned other communication platforms like Trellis and Slack. However, it was noted that despite their efforts, these platforms could not support the entire network due to the members' varying engagement methods. Other modes of communication include “our annual meeting where we communicate and update people on what is happening. Then there are regional meetings” (Global Network 2). Other approaches to staying relevant include platforms where “members can exchange. Though some of them were created 12 years ago and are now outdated, they were always bottom-up” (EU Network 1).

According to the National Network 2, although digital platforms such as Zoom meetings and webinars are beneficial, there is still a learning curve when it comes to effectively working with and facilitating them. Though digital communications have facilitated accessibility, Trans-national Network 1 reported discrepancies in the level of responsiveness to these digital platforms. It was further elucidated that more personal contacts were established through platforms such as WhatsApp.

Despite the rise of digital communication channels, conferences and workshops are still highly relevant: “we concretely facilitate PE through our conference. We have a website to facilitate sharing resources. We have 10 EU projects to facilitate this process” (EU Network 1). Similarly Global Network 3’s interviewee mentioned that they “hope we provide an unmissable conference.”

National Network 3 mentioned the importance of their PEN as “there are not a lot of science communication workshops in [our country], so the need is there.” To remain pertinent to members, it is crucial to “check what the needs of your members are… There must be something for everybody…where members see the value of being part of the PEN and using best practices to inspire their own PES work. That is what makes a PEN a success” (Global Network 2). Other approaches are to include members “in strategic discussions…involving them in the development of the network” (EU Network 2).

To stay relevant, EU Network 3 offered its members a “Vision—by offering them something more than they already have, more than they can accomplish on their own.” Global Network 4 also asked its members to suggest topics. National Network 2 stay relevant by “inspiring change in mindset and behaviour.” Another tactic is the facilitation of "science diplomacy" in an effort to strengthen their position. This involves bringing influential individuals to events or festivals in order to showcase their work and gain recognition for their contributions. As reported by EU Network 2, this strategy has proven to be effective in promoting both the individual and the organisation's endeavours, thereby ensuring their continued relevance in the academic community.

Global Network 4 indicated its willingness to develop relevant campaigns “to respond to the community’s needs…we introduced new protocols…[although] sometimes it is not financially or technologically feasible, but we try to be as responsive as possible, given the resources we have.”

Sub-code: 2.2.3 Supports good relationships between members and stakeholders

The PEN's ability to operate efficiently does not rely solely on its size and relevance, but also on its ability to promote healthy relationships among its members. This study investigated how effective management support can facilitate positive relationships between members and stakeholders in PENs. Global Network 2 indicated that “if you already have something in common, it is much easier to build trust to cooperate and to build friendship.” Trans-national Network 1 reported having a strong and long-lasting relationship with a university in Mexico, describing it as being like friends. EU Network 3 echoed this, stating that their “informal slogan is professional networking with friends in a friendly informal atmosphere to build good relationships.”

Similar goals such as “sharing a common belief and goal that it is the right thing to do” was highlighted by Global Network 1. PENs also provide formal and informal opportunities for regular social interaction among members, such as “welcome drinks and networking and dinner, which is very informal” (National Network 2), also echoed by EU Network 3. Global Network 2’s representative explained that “…having a beer supported the mutual understanding and built trust, with the most important thing about conferences being the coffee breaks.”

All members have equal access to communicate with the president, regardless of their position within the organisation (Global Network 1). The PENs provide a platform for members to connect with others in their field, exchange ideas, and find potential partners for collaboration (Global Network 2).

According to National Network 2, their conference is unique in that it does not follow a traditional academic structure. This allows for a diverse range of attendees with varying backgrounds to participate. As the conference has grown, EU Network 1 has implemented an effective strategy in its new strategic plan. They plan to invest in providing opportunities for members to better connect by offering half or full-day sessions. This will not only enhance the conference experience but also foster stronger relationships among members.

National Network 1 offers conflict resolution services for different types of disputes, including conflicts involving journalists or research sources. The board provides impartial opinions to support positive relationships.

Main category: 2.3 Stakeholder diversity

Most mentions by the interviewees were for researchers and scientists as a stakeholder group, followed by government and universities (see Table 6.3).

Table 6.3:

Frequency of stakeholders

Stakeholder	Frequency
Researchers/Scientists	64
Government	52
University	50
Other networks	48
Science centres and museums	36
Journalists	30
Academia	18
Educators	17
Partners in projects	16
Citizen scientists	7
NGO's	3

Sub-code: 2.3.1 Academia

There is a mention of stakeholders such as "staff members of science shops mainly with academic backgrounds" (Global Network 2) typically working as scholars at Universities.

Sub-code: 2.3.2 University

Global Network 3 mentioned that "many of our members work for institutions such as universities." PENs collaborate with universities in many ways, including "sponsorship and a corporate membership later on" (National Network 1). However, National Network 3 mentioned they "try not to limit [themselves] to people working in communication at Institutions/Universities."

In addition, "the annual science conference is based in one of the universities. Everything is done together, including other educational and networking activities" (National Network 1). Global Network 2 noted that "universities are getting more open towards society, not just dissemination [but] getting into contact with society and citizens" (Global Network 2).

Sub-code: 2.3.3 NGO's

Mention of NGOs by PENs was not high, and were only mentioned by a couple of PENs as they collaborated with them on some projects (Global Network 2).

Sub-code: 2.3.4 Government

According to PENs, one of their counterparts receives government funding, and they themselves had a lump sum to start with (National Network 2). The local government partnered with National Network 3 to fund part of their conference, while Global Network 1 is supported by the federal government of their country. National Network 1 stated that state agencies provide funds and support for attendees to travel to the conference, but also expressed hesitation in becoming a "puppet organisation."

Despite this, PENs acknowledge the importance of governments as stakeholders and aim to inform them about science communication policy-making (National Network 1). EU Network 1 utilises their magazine as a tool for advocacy and to make information accessible to everyone, including government bodies.

Governmental employees are still welcome to attend the conference, but their presence is to provide insight into government interactions rather than contribute to the science communication field (National Network 1). Global Network 4 noted that working with government organisations may come with specific regulations for employee engagement.

Sub-code: 2.3.5 Partners in projects

This sub-code delved into examining PEN's partners, particularly those involved in EU projects. EU networks and certain global networks predominantly brought this up. PENs act as facilitators by "overseeing the coordination, administrative, but not organisation in the practice of these events…When we join an EU project, we try to negotiate to have some of our members as 3rd parties" (EU Network 1). Furthermore, EU Network 2 mentioned they "see that there is a role for [their] members in the project so that they can engage and meet each other." EU Network 2 has reported that they receive numerous requests for assistance in writing EU projects. The organisation is currently being run by a part-time director who dedicates 12 hours per week to the cause. Additionally, a project manager is responsible for overseeing two EU projects and is currently traveling to connect members to the aforementioned projects.

Sub-code: 2.3.6 Educators

Educators were not popular stakeholders as most of the members involved in the PENs in this study worked in direct informal science education, such as science communication practitioners. However, Global Network 2 indicated its involvement as "there are 122 programmes and thousands of students and teachers involved…"

Sub-code: 2.3.7 Science centres & museums

Global Network 3 mentioned that "many of our members work for institutions such as universities or science centres." This is echoed by Trans-national Network 1 and National Network 3.

Sub-code: 2.3.8 Researchers/Scientists

With the exception of Global Network 4, the majority of PENs have a limited number of scientists within their membership. Nevertheless, Global Network 4 places a strong emphasis on supporting "scientists and engineers to do PES..." which addresses a common hurdle that many scientists face when getting started. Through ethical discussions, Global Network 4 collaborate with scientists to explore the role of values, morals, economics, and societal factors in decision-making regarding science and technology. National Network 1 mentioned that they "shape the ideas of our members as researchers or otherwise to address societal needs." Global Network 4 identified "core areas of training scientists working with researchers who study best practices, demonstrating what good PES looks like and working at the institutional level, how institutions support their scientists doing PES." Similarly, Global Network 3 that "over several years [we worked] with early career researchers and early postgraduate students." During conferences, researchers are included as key-note speakers (EU Network 1).

Sub-code: 2.3.9 Other networks

All the PENs see the importance of engaging with other networks. These could be similar PENs from different regions or smaller organisations within their countries where "we invite each other as networking of networks is also important" (Global Network 2). Similarly, EU Network 2 mentioned that they "are collaborating with other EU, Asian networks, especially and Chinese organisations." National Network 2 mentioned reaching out "through the partner network to communities and indigenous groups…and others."

Establishing connections with other "science communication networks to connect our activities on a European level to learn better from each other and engaging stakeholders" is essential (EU Network 2). This is also the case for Global Network 3 and interacting "with national science communication networks," which is also echoed by Global Network 4.

PENs are also invited to speak at other organisations and PENs by "offering a view of science communication that has developed from our PEN, offering a global view of trends, directions and patterns in science communication globally" (Global Network 3). Similarly, Trans-national Network 1 mentioned working with "other networks similar to our PEN, and having regular conversations." The involvement of other PENs is crucial as it helps prevent a narrow focus and encourages interaction with additional committees and organisations outside of the network (National Network 2).

Sub-code: 2.3.10 Journalists

It is worth noting that the majority of PEN members who participated in this study are not science journalists. However, National Network 1 mentioned that they are dedicated to supporting science journalists, especially given the current challenges faced by the community. According to them, social media in their country is facing a huge crisis, which has had a significant impact on science journalism. Despite this, there are still some excellent science journalists who have approached PEN and expressed a desire to grow with them. Similarly, Global Network 4 mentioned giving their members the experience "to work as a science journalist for the summer…"

National Network 1 stated that they "have an award for science journalists, and the national competition sends participants to the European science writer of the year in partnership with the foundation, infrastructure and educational programmes, so they support us." This recognition enhances the standing of the awardees in the field.

For National Network 2, “many of our members have science blogs nationally.” However, there is a specialised national organisation for journalists which was government-funded to disseminate science news better.

Sub-code: 2.3.11 Citizen scientists

Global Network 1 mentioned the role of “citizen scientists [to] help understand what their local environment is all about and how they can learn about it through using the app and data collection.” According to EU Network 3, one of the stakeholders involved in their projects has emphasized the importance of science communication and citizen science projects. The PEN stated that effective communication plays a vital role in the success of citizen science initiatives, with 60% of the project's outcome depending on the communication strategy (EU Network 3).

Sub-code: 2.3.12 Other

Other codes that did not fit within the other sub-codes include stakeholders that were mentioned from industry, the European Commission, students, accountants, representatives from host organisations of the conference, influencers, and others.

Sub-code: 2.3.15 Stakeholder experiences

Stakeholder experiences that impact the network, such as reputation and resources, were analysed. Out of all the experiences Global Network 1’s interviewee stated that “the negative parts that happen are 0.000001 per cent.”

Observations suggest that there was inadequate collaboration with government stakeholders, as they neglected to send a representative to the conference (National Network 1). Another instance involved the investment of considerable time with certain stakeholders, such as when they cooperated with a major stakeholder who invited them to participate in their research, yet the collaboration ultimately proved unsuccessful (EU Network 1).).

Observations suggest that there was inadequate collaboration with government stakeholders, as they neglected to send a representative to the conference (National Network 1). Another instance involved the investment of considerable time with certain stakeholders, such as when they cooperated with a major stakeholder who invited them to participate in their research, yet the collaboration ultimately proved unsuccessful (EU Network 1).

National Network 3 managed to avoid a negative experience as -

> We were invited to join a consultancy committee for a science communication event where we were asked to provide scientific approval for the program and speakers. However, we had to withdraw from the committee as we were expected to approve names and content without

> being provided with any details about the event. We could not associate ourselves with something that could potentially harm our network, and hence we chose to withdraw. (National Network 3)

EU Network 1 expressed their disappointment stating that eliminating SwafS was a step backwards, which they opposed. Additionally, EU Network 3 raised the issue of time constraints, acknowledging that their members are occupied individuals who may not be able to attend the conference.

National Network 1 mentioned that so far, "they have not had any reputation damage" from their members, whom they consider their "biggest stakeholders that might potentially contribute to any negative experiences."

PENs are highly selective when choosing partners and acquiring "funding to make sure that we and the funder have the same message, and to make sure that network members are comfortable with that funding and appropriately thought through" (Global Network 4). Furthermore, Global Network 4 stated that it is crucial to consider the potential impact on the network's reputation when partnering with industry sponsors. The perception of receiving funding from a pharmaceutical or oil company could have consequences that necessitate careful deliberation before accepting such partnerships. EU Network 2 indicated that "it is not a problem to involve individuals, but you cannot involve everybody in a Horizon 2020 project, because of how it is framed. In certain institutions, it is hard to involve individuals."

Other stakeholder experiences include the integration of different cultures within the network. Presidents also noted the delicate intricacies that management must consider when planning activities among cross-cultural countries in a global context (EU Network 3).

Positive stakeholder experiences include engaging with diverse and underrepresented groups in society such as their members' involvement in "ethical issues regarding the research, approaching vulnerable groups, children, working with informed consent forms and having a specific language" (Global Network 2). Trans-national Network 1 mentioned that what they lack in funds, they "can share in experience… as inclusivity was always a relevant topic for us and it is a strength."

National Network 2 has brought to light a significant challenge pertaining to the stereotyping of indigenous knowledge on Facebook groups. This issue goes against their code of conduct that advocates for the respect and dignity of all individuals. It is imperative to ensure that no one feels belittled or marginalised based on their cultural background. Therefore, the network has taken necessary measures to shut down such behaviour and promote inclusivity and diversity.

PENs have been used to advance social causes via their platform to "address societal challenges mainly climate change, biodiversity and inclusiveness" (EU Network 1). Other positive experiences with stakeholders included gifting their "members with a special edition magazine…and cross-promoting each other's work" (National Network 2).

While EC listened to science shop representatives, science shops are now "involved in the research and innovation activities" (Global Network 2). Other positive experiences recognised by the PENs mentioned enduring relationships (Trans-national Network 1). Another positive experience mentioned an "advocacy campaign we ran for two years with EC…as we needed them to connect at a national level with their Members of the European Parliament (MEPs)" (EU Network 1).

EU Network 3 recognised the challenge that "when you start a collaboration on something new in an organisation that is structured like our PEN, it is a challenge to make sure it is sustainable, as there is no structural umbrella to ensure continuity." Global Network 2 expressed positive feedback towards establishing novel networks that foster opportunities for potential collaborations.

6.3 Conclusion: Summary of the qualitative results

This study examined the structures of PENs, which encompassed varying hierarchical levels.

- Management faced difficulties in managing time while juggling full-time jobs, and PENs adopted different leadership styles.

- Senior management's primary concerns were to remain relevant by providing valuable services to their members and ensuring the survival and sustainability of the PEN. While policies related to the election process and governance structure can support sustainability, the key challenge lies in securing the necessary resources for the network to thrive.

- Most networks reported that their leadership style was characterised by commitment, trust, openness, and co-operation.

- Membership fees, EU project funds, grants from foundations, sponsorship for specific activities such as conferences, and personal funds are among the funding streams mentioned by interviewees.

- When it comes to membership, there are varying opinions among PENs. Some are eager to increase their membership base, while others are more cautious due to financial considerations and prioritise quality over quantity. Regardless of their approach, all PENs strive to remain relevant, which can be a challenging task. In addition, maintaining the current number of members is also a key concern for many PENs.

The scoping analysis conducted in Chapter 3 provides a foundational understanding of how countries globally involve citizens in public engagement with science (PES) through national documents that mention PES. This international perspective sets the stage for examining local contexts in Chapters 4 and 5, where the specific structures and frameworks that shape the relationships and dialogues between citizens and science are explored. Drawing on Habermas's (1973) concept of the public sphere, these chapters highlight how power dynamics influence who participates in scientific discourse and decision-making processes, particularly in relation to Bourdieu’s (1986) theory of capital, which asserts that social and cultural capital significantly affect individuals' engagement with science. Chapter 6 builds upon these findings by presenting qualitative data collected from interviews with senior management staff of PENs from various institutions engaged in PES. This chapter identifies two key themes, each with sub-codes as detailed in Tables 6.1/6.2, derived through deductive and inductive coding methods. These themes provide insight into the operational dynamics of PES within the Maltese context and reveal how institutional practices can either facilitate or hinder public engagement.

Chapter 7

Discussion:

Breaking the hegemony and shifting paradigms

7.0 Introduction

This chapter conducts a detailed analysis of the findings presented in Chapters 3-6, highlighting the key outcomes and their significance in the context of science communication in Malta. This analysis will provide a comprehensive understanding of the implications and salient points that emerged from the results.

7.1 The Maltese public sphere of science (PSS)

7.1.1 The Maltese social structure – the fragmentation

Although science is often regarded as a reliable and objective pursuit of knowledge (Chalmers, 2013), it does not imply that it is an isolated endeavour. Various factors, including gender, race, class, and access to power, significantly impact the production and reliability of scientific knowledge across different temporal, spatial, and cultural contexts. These forces often shape the scientific knowledge production process, going beyond the scientific pursuit itself (Lewenstein, 2019).

This chapter employs an intersectionality lens to analyse how social structures impact citizens' scientific identities in tandem with institutions and entities that conduct Public engagement with science (PES). Drawing from Habermas's public sphere, this analysis investigates the power dynamics in the Maltese Public sphere of science (PSS) and explores how inequalities and fragmentation in PES contribute to citizens' disengagement with science.

Understanding the factors contributing to students' furthering their STEM studies is essential (OECD, 2020). This study also emphasises its significance locally, echoing the sentiments of all the entities interviewed who view it as a key driver for conducting PES. This study sought to describe citizens' habitus by examining their highest education qualification, current residence, preferred learning mode, and attendance to science activities linked to their self-perception of science. The relevance, role and accessibility of science are linked to the perception of how science is seen by Maltese residents, which in turn affects how society interacts and engages with science. Understanding the logic with which the capital of science operates – which practices constitute it, how it is acquired, what its exchange value of profitability is and to which cultural arbitrariness it caters is essential (Moris et al., 2022) in the realm of PES in the PSS.

Scientific entities significantly influence science education at various levels, ultimately impacting the public's accessibility to science (Jensen & Wright, 2015). The accepted definition of science, or rather the hegemonic understanding of science, lies at the centre and refers to the conventional understanding of scientific knowledge and inquiry within a given society or community. This definition is often shaped by influential scientific institutions, prevailing academic norms, and cultural perceptions of science, that tend to align with the interests and perspectives of dominant groups. It encompasses methodologies, theories, and practices that are widely recognised and validated within the scientific community, reflecting a consensus on what qualifies as legitimate scientific endeavour.

Gramsci posits that hegemony is not merely about coercive power but involves the consent of the governed, achieved through cultural institutions that propagate specific ideologies (Badino and Omodeo (2021). My study contends that the practice of science is not a neutral endeavour; rather, it is significantly shaped by institutional dynamics stemming from broader political and social forces. Moreover, it contends that how science is viewed can serve to maintain or reinforce existing power structures that consequently lead to fragmented positions amongst drivers for PES. By unpacking these dynamics, the study aims to shed light on the inherent biases and complexities within the construction of scientific knowledge and, in turn, how they affect PES. Moreover, this hegemonic framework can marginalise alternative forms of knowledge and inquiry, particularly those arising from underrepresented groups.The qualitative results also suggest that local employees' vision for PES tend to align with the entity's vision. Throughout my research, I observed a pattern of upper management changes across many entities, including MEYR, Esplora, and MCST[22]. Each new leadership team brings their own priorities and vision, leading to a shift in focus for the entity. This can create new networks that grant access to some individuals while excluding others. While the impression may be that these entities are open to all, in reality, multiple gates and gatekeepers control accessibility. Furthermore, the overall research found that even within the higher levels of management, access to affect change is limited based on an individual's social capital. Although being associated with a particular entity may enhance one's influence, it is not a guarantee of access to a higher level of engagement. Access is also influenced by cultural values, power structures, education, and family background, which are replicated at different societal levels and build the relevant social capital needed to effect change. My international interviews indicate that these patterns of access and engagement are not unique to a particular region, but rather exist at an international level among PEN members, non-members, and management, with some PENs having more power to effect change at the EU level.

Bourdieu (1986) emphasised the ability to use social connections to gain diverse types of capital. In contrast, Archer et al.'s (2015) emphasis lies in the individual's agency to configure their social networks to align with their personal objectives. Approval from the inner circle is a prerequisite for implementing any changes. Those who are not part of the power-wielding centre decision-making process and are on the periphery can opt to potentially impede progress when this is deemed negative or aspire to bring any change to the established hegemonic understanding of science. This was evident in the Coordinated Science issue in the early 2000's (Times of Malta, 2007). The proposal for Coordinated Science, introduced by a focus group of science education experts set up by the National Curriculum Council,

[22] Now referred to XjenzaMalta

was ultimately rejected due to numerous objections from science-oriented faculties at the UM. They believed the reform would negatively affect the enrolment rates in science degree courses.

Citizens' scientific forms of cultural capital, science-related behaviours, and science-related forms of social capital influence citizens' willingness to engage with science beyond science education (Archer et al., 2015). Although the notion of science capital sheds light on the influence of social inequality in science education, it falls short of providing a comprehensive perspective. Like the deficit model, science capital places emphasis on citizens' insufficient resources (Jensen & Wright, 2015). Although citizen empowerment has potential benefits, the approach may inadvertently assign blame or imply that citizens require remediation. The human being is not a blank slate without any innate ideas or knowledge. We acquire new knowledge through sensory experience and reflection (Androne, 2014) and we continue to accumulate knowledge even after compulsory schooling has ended (Staus et al., 2021). This ongoing accumulation occurs through various means, such as reading news articles about climate change or health on the internet, visiting science centres, and attending dialogic activities.As Jensen pointed out in criticism to Archer's view of the science capital, this analysis turns a critical lens towards the systemic pattern throughout society by understanding the role that entities that conduct PES have in reproducing exclusionary publics' engagement in science. It is also worth noting that the international science establishment influences the local scene, determining who should engage and how suggesting power-based fragmentation rather than coherence.

7.1.2 Successful PES? ... or is it?

This study showed that entities conducting PES claim they successfully engage citizens through their outreach events. Nevertheless, some of the Maltese interviewees did not clearly indicate the level of engagement with citizens and other publics with science. Conversely, PEN interviewees stated that the management is constantly looking for ways for their members to engage minorities with science (explored in further detail in 7.2.2).

Some of the Maltese interviewees, such as UM and MEYR, failed to mention whether any form of evaluation is in place to assess the claimed success (see Chapter 5). Locally, the interactive science centre has engaged an external research and consultancy company to evaluate citizens' attitudes towards science (MISCO International Ltd, 2019). Jensen and Gerber (2020) point out that funders often do not question the quality of the evaluation of science communication activities and that external evaluators tend to offer limited value in evidence for improvement. Possible explanations for this lack of evaluation include inexperience with conducting evaluations and time constraints.

An interviewee from my study stated that subsequent to the inauguration of Esplora's Science Centre in 2016, there had been a noteworthy surge of 14% in the number of individuals who perceive science in a more favourable light. However, while positive this increase cannot be conclusively attributed solely to Esplora. Establishing a cause-and-effect relationship between outcomes can be challenging and prone to significant issues (Staus et al., 2022). Other local activities by various sectors could have contributed to this increase. The observed effects stated by MCST4C could also be attributed to self-selection bias or methodological flaws (Jensen & Lister, 2016). Further analysis is required to establish a direct correlation between the centre's initiatives and the observed change in publics' perceptions.

Internationally, informal science learning institutions are increasingly expected to demonstrate visitor impacts beyond their immediate visit (Jensen & Lister, 2016). Most informal science learning research captures the results of short-term experiences rather than the accumulation of knowledge (Staus et al., 2021). While, Esplora has released several reports detailing citizen attitudes towards science (MISCO International Ltd., 2015, 2019; National STEM engagement working group, 2022), these reports do not necessarily include information regarding behavioural changes exhibited by citizens beyond simply enjoying science. Challenges associated with capturing such information are related to the specific learning pathways unique to each individual (Falk & Pattison, 2018), and it is difficult to measure any change over time (Taplin, 2005). While longitudinal studies are favoured to capture the long-term effects of informal science education experiences, methodological limitations are attributed to attrition (Bauer, 2004). Attrition rates could arise due to loss of interest and loss of contact, which can be mitigated using multiple retention strategies, contact methods, and statistical techniques (Staus et al., 2021).

The importance of building human resource capacity is recognised by countries worldwide, which adopt various strategies to achieve this goal. Examples include Zambia (Ministry for Higher Education 2020), United Kingdom (Archer et al., 2015), Ireland (Government of Ireland, 2022), New Zealand (New Zealand Government Ministry of Business, Innovation and Employment, 2022), and South Africa (Republic of South Africa Department of Science and Technology, 2019), which focus on the local scene and attract the best students and research talent globally. In Malta, educational institutions face intense competition to attract students to enrol in their courses. My research indicates that UM and MCAST are mostly driven by the need to keep a steady flow of students once compulsory schooling has ended. The task is arduous, given the scarce pool of available students for consideration in Malta. One of the reasons could be due to the decreasing birth rate trend that Malta is currently experiencing. According to Eurostat, in 2021, Malta had the lowest birth rate in Europe, at 1.13 live births per woman (Eurostat, 2023). As a result, both UM and MCAST employ marketing strategies to achieve enrolment goals. In Malta, the Ministry of Education and Esplora also aim to meet the country's skilled workforce needs. The European Union is taking action to support and encourage young people who are interested in pursuing careers in science. Their efforts include initiatives like the EU Year of Skills, which focuses on developing digital and green technology skills (European Commission, 2024). Interestingly, the EU is also working to improve accessibility for students from diverse backgrounds, including those who may have negative or indifferent attitudes towards science. This suggests an approach that involves addressing and dealing with students' negative perceptions rather than addressing the systemic inequities in and within the PSS.

One of the main reasons scientists communicate and engage students is to inspire the next generation of scientists (Ho et al., 2022; Cerrato et al., 2018; Farrugia, 2015). As previously mentioned both in this discussion and the results, one of the primary motivators for entities to engage in PES is student enrolment. My study demonstrated strategies that these entities employ in engaging students and their guardians in science and research, ensuring a steady stream of students. Although interviewees, such as UM2, in my study (see Chapter 5) may state that their motivation is centred on fulfilling their mission as scientists and educators to inspire the next generation of scientists, a stark reality from observations throughout my work with academics is that their job security within their organisation is dependent on student enrolment. In view of this, I believe that ensuring job security may also be an underlying objective behind their motivation for engaging students for subsequent enrolment.

The economic demands and job market creation are crucial drivers identified by UM, MCAST, MCST, and MEYR (as can be seen in Subcode 1.2.2 Economic needs)[23]. The Malta Chamber of Scientists (MCS), in its 2016 policy document, highlighted the country's underperformance in the scientific community, which has resulted in a dearth of skilled workers for the modern-day economy. This assertion is not unwarranted and calls for an enabling environment that promotes greater diversity in research and career paths, spanning academia and industry, as also recognised by New Zealand's strategy (Ministry of Business, Innovation and Employment, 2022). This underscores the shared challenges faced by nations despite their geographical distance. Maltese interviewees claimed that research is essential for Malta to stay competitive on an international scale. Furthermore, a link was made between student uptake and having a skilled workforce. MCAST emphasised the need for industries to have well-versed and job-ready students, and UM's contribution was to address industries' requirements.

In 2022, 66% of Malta's companies struggled to find workers with a suitable skill set, although the Ernst & Young Ltd Report (2022) indicated a slight improvement from the previous year. Industry looks towards Maltese educational institutions to fulfil the need for a workforce ready to work in their companies. According to NSO (n.d.), a mismatch exists between the necessary skills and the educational qualifications of workers in the information and communication industry (25.4%) and other industries such as manufacturing, mining, and quarrying (22.9%). These industries have reported a higher percentage of under-educated workers for the job. Although often used interchangeably, there is a difference between education and training (Newland, 2008). Education addresses the broader scope of providing a holistic development of individuals (Witt, 2008) that focuses on fostering critical thinking, creativity, and personal growth. Alternatively, training refers to the process of teaching specific skills or competencies required for a particular job or task. Training is, therefore, more specialised to perform specific functions or tasks effectively. Incorporating experiential and inquiry-based learning is an essential aspect of education that complements the traditional academic content. This approach provides hands-on, practical experiences that enable learners to apply theoretical concepts and gain valuable

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[23] Refer to p.87-88

skills. By doing so, learners can deepen their understanding of complex subjects, develop problem-solving abilities, and enhance their overall learning experience (Constantinou et al., 2018; Ravel et al., 2018).

In tune with this, in 2015, the Malta Further and Higher Education Authority (MFHEA) responsible for accrediting and auditing higher education institutions, established standards in order to ensure the acquisition of knowledge, skills and competences through educational programmes offered. This, while attending to the student diversity and their needs, enabling flexible learning paths through flexible pedagogical methods and retaining a coherent National Qualifications Framework. The MFHEA document (2015) presently being implemented by recognised higher education insitutions also requires the use of mechanisms that ensure ongoing monitoring and periodic review of programmes offered, in order to ascertain that they remain up-to-date with au-courant research, with the changing needs of students, related sectors, stakeholders and society and to encourage portability of qualifications and mobility in terms of employment across Europe.

The implementation of such pedagogical approaches can be seen as a means of equipping students with not only the necessary skills to become valuable contributors to the workforce but also with the critical skills required to be active and informed citizens. Through the cultivation of an ability to question prevailing power structures both in and outside of entities, students are empowered to engage in important societal dialogues and challenge the status quo. Improved communication and establishing realistic expectations by both the industry and higher educational institutions would lead to better experiences for all involved. Based on the interviews from my study, MCAST appears to tailor its courses to the needs of industry, while UM's focus is not necessarily on preparing students for a specific job, except for certain professions such as teaching and architecture. I believe that collaborative specialised training between educational institutions and industry could prove beneficial, countering the common misconception in society that learning ceases after graduation. It is best to provide such activities as part of non-formal education through lifelong short courses instead of formal education. This approach offers a flexible and informal learning environment that allows individuals to acquire new knowledge and skills at their own pace and convenience. This claim is supported by an OECD report that asserts that individuals with higher levels of education tend to engage in lifelong learning more often and, particularly when labour markets are unfavourable, young people tend to stay in education for a longer time (OECD, 2023b).

The National Skills Council's conference in 2023 addressed six crucial points related to skills development in Malta’s non-formal learning environment (National Skills Council, 2023). Considering these points, Malta has taken a much-needed initiative to establish its first Skills Strategy, also in tune with the MFHEA (2022), vocational education, and training institutions' (VET) standards. This strategy is expected to bridge the gap successfully and serve as a liaison between the industry and formal education institutions. Nevertheless, the crucial areas identified in the conference, such as active citizenship through lifelong career guidance and continuous professional development through training, should be given due attention to ensure a well-skilled workforce in Malta's non-formal learning environment (National Skills Council, 2023).

In my research study, UM and MCAST saw scientific excellence as a way to drive excellent research and propel the country forward enabling it to respond to local and global needs (Refer to Subcode 1.2.3)[24]. Nonetheless, scientific excellence needs to be explicitly stated and should also include researchers who can engage with several stakeholders and citizens. Maltese entities' contribution to PE tends to be through top-down activities, similar to the deficit model. The 2016 Malta Chamber of Science policy defined PE only in terms of citizens' appreciation towards science (MCS, 2016). As indicated by MCST3F, simply hosting events at Esplora that only showcase the results of researchers' projects without involving meaningful conversation and interaction during the project cycle is unproductive. Both personal experience and literature show that, while such events may be required, they are of little value unless they are accompanied by active participation and dialogue throughout the entire project lifecycle. According to the UM interviewees, their dissemination strategies are closely tied to the need to obtain funding, whether it be from MCST or EU sources. This highlights the critical role that funding policies play in shaping how and when they interact with citizens and ultimately determines the nature of their citizen engagement efforts. RRI and community involvement should not simply be another checklist item to be ticked to satisfy funders (Levikov et al., 2020) or a top-down perspective. Instead, it is crucial to acknowledge how new knowledge and ideas are created within society (Jakobsen et al., 2019).

The Committee for Research Engagement (CRE) was designed to address and incorporate RRI and engaged research at UM (UM, n.d.), yet maintaining citizen involvement in research projects is a challenging and ambitious task (Macnaghten, 2020). RRI principles are ideal, but the framework lacks models that effectively incorporate innovation that impacts society. There is a lack of critical dialogue regarding the societal and environmental impacts of economic growth. Citizens can contribute to finding better solutions for their local and global well-being. While UM interviewees from my study mentioned that certain research may not require the involvement of citizens, it is worth noting that institutions like the European Council for Nuclear Research (CERN) invest considerable resources in engaging diverse audiences, even for research that may not have direct practical applications in the daily lives of citizens (Conseil Européen pour la Recherche Nucléaire (CERN), 2023). This highlights the varying approaches entities take towards citizen involvement in research, with some emphasising the importance of engaging citizens regardless of immediate practical applications.

The qualitative findings of this research (see Chapter 5) suggest that MEYR expressed its intention to extend its reach to stakeholders beyond the conventional boundaries of formal education but stated that

[24] Refer to p. 177

they have been apprehensive about venturing out of their comfort zone, despite acknowledging the significance of these stakeholders. On the other hand, MCST has taken a step forward by engaging a diverse group of stakeholders, the National STEM Engagement Working Group, tasked with creating a comprehensive National STEM Engagement Strategy by implementing various initiatives. However, despite aiming to finalise this strategy by 2022, it has yet to be completed. Possible reasons for this delay include a lack of direction and ongoing changes in management structures exacerbating the existing fragmentation.

My results indicate that various entities acknowledged that the media shapes public perception of science. Recognising the necessity for enhanced dissemination of scientific information to citizens, entities like MEYR have recognised the imperative to refine their communication strategies. Similarly, UM aims to leverage media to promote its research. However, despite these acknowledgements and efforts, empirical research delineating the intricate relationship between media and citizens remains sparse.

On the local scale, few people consistently produce high-quality content on our islands that balances education and entertainment (edutainment) without compromising the substance. For example, while the UM produced research magazine THINK publishes excellent articles it could benefit from a wider reach.

Many scientists and educators are apprehensive about social media and its impact on public discourse (Keng & Cheng, 2023). Nonetheless, social media offers accessible spaces for unfiltered interactions between different publics (Habermas, 2022). Drawing from experiences such as the COVID-19 science communication project launched in March 2020, which predominantly utilised social media, valuable insights have emerged. Key learnings encompass the significance of cultivating trust with the audience, addressing misinformation directly, furnishing specific and accurate information, and presenting it in an easily digestible format (Albrecht et al., 2022). These insights serve as guiding principles for future endeavours aimed at mitigating infodemics and enhancing scientific communication during public health crises.

The COVID-19 pandemic served as an exceptional case study. Medical professionals, researchers, and scientists employed simple explanations to engage citizens in mitigating the spread of the infection and emphasising the significance of vaccination. As a result, promoting public engagement during this period proved to be less difficult than expected. However, despite noteworthy technological advancements, policymakers and practitioners are still confronted with persistent challenges. These include fostering citizen engagement through innovative technologies that are still in their developmental stages, such as vaccines (Albrecht et al., 2022).

7.2 Challenges to engage in PES

The following section links my empirical data with the theoretical frameworks of capital (Bourdieu, 1986) and the public sphere (Habermas, 1992), exploring how these concepts influence citizen and publics' participation and engagement within PES. This interplay can perpetuate hegemonic power dynamics, as Badino and Omodeo (2021) noted. By examining how different forms of capital (Bourdieu 1986) shape individuals' access to scientific discourse, we can better understand the barriers that different demographics face in participating in the public sphere. Furthermore, the findings from my study reveal that these barriers are not merely individual shortcomings but are deeply rooted in systemic inequalities and cultural norms that dictate who has a voice in scientific discussions. This framework sets the stage for a deeper exploration of the empirical results presented in the subsequent sections, particularly regarding how these dynamics manifest in the Maltese context and influence how publics engage with science and technology.

7.2.1 Citizens' Habitus/Capital in the scientific field

7.2.1.1 Interest in science

My local citizens' questionnaire found that 56.3% of individuals feel knowledgeable about science, technology, and innovation, with 80.2% expressing a keen interest in the subject. These results align closely with MISCO's reports on public perception of science, which revealed that 55% of participants were interested in science in 2015, and that percentage rose to 64.1% in 2019 (MISCO International Ltd, 2019; MISCO International Ltd, 2015). As already stated, while this rise in percentage is welcomed, it can be attributed to several initiatives and entities conducting PES, rather than just the opening of Esplora. On an international scale, according to a study by Wissenschaftsbaromenter and Eurobarometer, up to 60% of respondents from Germany expressed interest in science and research 246 (Askvall et al., 2021). Based on the available data, it can be observed that Malta exhibits a level of interest in science that is consistent with global benchmarks.

7.2.1.2 Interest in science and education level

My study showed that Maltese residents tend to associate science with academic subjects, with over 39% of respondents making this connection. The category of feelings, such as interest, fun, curiosity, and difficulty, was the second most commonly associated category with science (see Chapter 4). MISCO International Ltd's report (2019) indicated that citizens desire to learn more about the subject but still find it difficult. During my data collection process, it was observed that many respondents initially expressed feelings of inadequacy about their scientific knowledge and that their opinions on the subject were unimportant. Many participants associated science with a content-based subject, a perception which may have contributed to their reluctance to participate fully in the study. An interesting observation from my study was the tendency of some parents to encourage their children to fill in the questionnaire, as they believed their children had more knowledge of science than they did. This trend was particularly evident as younger respondents were generally more willing to participate in the study than older participants, who expressed more hesitancy. This generational difference in participation rates could be attributed to the increased accessibility of scientific knowledge and its relevance in the lives of younger Maltese residents. The common belief in Malta that science is a difficult and complicated subject can lead to the mistaken idea that it is only suitable for people with exceptional cognitive abilities. In my view, it is crucial for citizens and entities to recognise that science involves learning about scientific principles and using logical, analytical, and evidence-based thinking. It is through this approach that the misconception that science is exclusive to the intellectually elite is dispelled.

Based on the results of my questionnaire, it seems that there is a relationship between an individual's highest level of education and their level of interest in science. The data shows that respondents with a secondary level of education had the lowest percentage of interest in science, at 41.7% (see Table 4.18). This could suggest that the current secondary school curriculum in Malta may not be effectively fostering curiosity and enthusiasm for the subject, but geared to those who want to further their studies in science.

Moreover, studies in the U.S. indicate that individuals with higher educational attainment tend to have more favourable attitudes towards science, technology, and scientists (National Science Board, 2020). Furthermore, research conducted in the United States indicates that individuals with higher educational attainment are generally more inclined to exhibit favourable attitudes toward science, technology, and scientists (National Science Board, 2020). However, it is crucial to approach these findings with caution, as the evidence establishing a robust relationship between education, knowledge, and attitudes remains relatively weak. Although there is a suggestion of a positive correlation, the strength of this relationship is not particularly pronounced. While the direct correlation between education level and interest in science is not mentioned in other countries, several countries (e.g. Singapore, China, Australia and others) have conducted surveys to understand if citizens have a basic understanding of science (Liu et al., 2019; (Australian National Centre for the Public Awareness of Science (CPAS), 2018; Ho et al., 2015). One possible explanation for this trend is that individuals with higher education levels may feel more confident in their ability to comprehend scientific concepts, which could reinforce the idea that science is a challenging field. The Public Understanding Science movement has reinforced the idea that the primary deficit in scientific communication lies with citizens and not within scientific institutions. This movement was fueled by the concept of "the more you know, the more you love it" (Cámara et al., 2018, p.291), emphasising citizens' role in gaining knowledge and understanding of science. Further supporting this notion, Johnson and Peifer (2017) also stated that there is a clear correlation between respondents’ level of education and higher confidence in researchers in the U.S.

My research showed that the highest educational qualification of respondents played a significant role in their tendency to attend science-related activities. Those with higher education qualifications, such as undergraduates and postgraduates had a greater likelihood of attending such events than those with primary or secondary education (see Table 4.24). Jensen et al.'s study (2021) also confirmed that the highest education qualification is a factor in increased attendance at European Researchers Nights in Ireland, the UK, and Malta. However, the study also noted that the disparity between the education level in the three countries is higher in Malta, where nearly half (48%) of the Maltese population holds no formal qualification (Jensen et al., 2021). While PES events are meant to be inclusive, they may not effectively address existing patterns of exclusion. A possible solution could be to hold similar festivals in lower socioeconomic areas. For example, Esplora held the Esperimenta Tikka Xjenza festival, which targeted Cottonera and Kalkara residents to show science's relevance in citizens' daily lives (National STEM engagement working group, 2022). As seen in Table 4.52, proximity to a learning institution significantly enhances accessibility for students, thereby fostering higher rates of attendance. However, attendance data suggests that proximity alone does not necessarily increase participation from residents of the South of Malta, indicating a need for further research to understand and address barriers to engagement. It is worth noting that yet another critical aspect that significantly influences citizens' engagement in the PSS is the prevalence of citizens' education levels both locally and internationally. This finding suggests that exploring diverse engagement strategies adopted by other countries could potentially offer valuable insights into effectively addressing this issue. 7.2.1.3 Interest in science and respondents' socioeconomic status

Archer et al., (2015) suggest that low socioeconomic status is often linked to low science capital. Families with greater science capital are typically more likely to pursue science beyond formal education. In my view, the goal of PES events should be to encourage children and adults to pursue science and cultivate critical and engaged members of society. The dichotomy between individuals who opt for a vocation in scientific fields and those who can proficiently engage with scientific concepts in their day-to-day activities is quite apparent. The concept of science capital implies that once individuals possess adequate content knowledge and certification, the path forward to PES and affecting change is wide open. Based on my empirical analysis, it is my contention that the door only remains slightly ajar. Although my data did not directly measure family income or access to specific resources, it reveals that respondents with higher levels of certification attend science events more frequently than those with only primary or secondary education (see Table 4.18). This trend suggests that individuals from lower SES backgrounds may possess lower levels of science capital.

7.2.1.4 Interest in science and respondents' preferred knowledge channels

My local questionnaire showed that UM was the most preferred learning entity among the respondents, followed by NGOs and MCST. UM is the most trusted source of information, probably because it is a relatively independent and trustworthy research entity. MISCO International Ltd.'s report (2019) indicated that Maltese residents trust people who are considered experts. Nevertheless, the Government scored the lowest in this study despite still being considered positively by the respondents. One possible explanation may be that citizens are aware of the frequent turnover in government positions, where political interests often sway the trustworthiness of shared information, particularly in light of re-election prospects. This was evident during the COVID-19 pandemic, where political leaders across the globe claimed to be ‘following the science,’ even though the scientific community had diverse and contested opinions (Askvall et al, 2021). These findings highlight the need for transparency and objectivity in research and decision-making processes. Echoing the sentiment expressed by Cámara et al. (2018), Wynne (2006) disputes the commonly-held belief that citizens lack trust in science due to their lack of knowledge about scientific concepts. Rather, Wynne (2006) argues that the root cause of this mistrust lies in the scientific community's failure to comprehend and address the viewpoints and apprehensions of citizens. Askvall et al. (2021) claim that institutions, experts, and citizens must establish clear, transparent, and reliable communication regarding all aspects of science from its inception to its ongoing development.

7.2.1.5 Interest in science and respondents’ age and preferred communication channels

This study found a correlation between age and preferred modes of learning. MISCO International Ltd.’s report (2019) indicates that younger individuals gravitate towards the internet, particularly social media platforms like Facebook, while older individuals prefer traditional sources such as newspapers (see Table 4.44). This trend is not unique to Malta; social media usage as a primary information source has surged in the UK and Europe (European Parliament, 2022a), driven by Facebook's growth from 4% in 2014 to 15% in 2019 (Department for Business Energy and Industrial Strategy (BEIS), 2020). Locally, organizations are leveraging social media to promote research projects and science-related events (National STEM engagement working group, 2022). While social media effectively engages audiences, it is crucial to investigate its impact on communication within the Maltese public sphere of science (PSS). Although MISCO employed systematic telephone surveys, it lacked open-ended questions about participants' perceptions of science. My research expands on MISCO's findings by including qualitative inquiries that explore how citizens engage with science.Findings from the Maltese interviewees also suggest that physical newspapers and the radio are becoming obsolete. From my experience working in the media, radio programmes can be transformed into online podcasts to better with younger audiences. The Eurobarometer report highlighted that television remains the primary news source (75%) (European Parliament, 2022). Additionally, the report indicates that Europeans are generally confident in their ability to recognise misinformation and fake news, although this trend tends to decrease with age and increase with education level (European Parliament, 2022). It is imperative for entities to have a comprehensive understanding of their audiences in order to create effective campaigns. This understanding plays a critical role in increasing the accessibility of information and determining the ways in which all citizens want to engage.

7.2.1.6 Interest in science and respondents’ gender

Considering Habermas's (1974/1973) concept of the public sphere, gender plays a significant role in shaping interest and engagement in science. Habermas posits that the public sphere is a space for rational discourse, where diverse voices can participate in discussions that influence societal norms and values. However, this space is often dominated by prevailing cultural norms that can marginalise certain groups, particularly women. However, this space is often dominated by prevailing cultural norms that can marginalise certain groups, particularly women. My study reveals that males tend to have higher self-perceptions of their scientific abilities compared to females. Self-perception is a factor influencing the attraction of women to study science, specifically in the physical sciences, contributing to gender imbalance (Ikkatai et al., 2021; Piatek-Jimenez et al., 2018). This disparity reflects the power dynamics within the public sphere, where traditional gender roles and stereotypes can inhibit women's participation and interest in scientific pursuits. Bourdieu's (1986) theory elucidates how social and cultural capital impacts individuals' experiences in STEM fields. Women’s underrepresentation in science is not merely a result of individual choices but is deeply rooted in systemic inequalities that limit their access to the necessary capital for success. According to UNESCO (2019), women comprise a minority of the world's researchers. Addressing the issue of gender diversity requires acknowledging the influence of cultural norms on personal and gender identities, emphasising the need for a comprehensive approach.

Numerous efforts are being made at local and international levels, including the annual celebration of the International Day of Women and Girls in Science and Technology on February 11th, to combat societal stereotypes, even though changing attitudes alone is not enough to drive behavioural changes (UNESCO, n.d.). This study showed that females listed science events as a preferred learning source. Similarly, according to SITC’s festival report, females constitute the majority of festival attendees (Qualia Analytics, 2021b, 2021a, 2020) but were only slightly skewed towards female respondents in 2023 (Qualia Analytics, 2023). This trend could be attributed to females holding higher educational qualifications or perhaps because such events are family-friendly and females are traditionally considered the primary caregivers in Malta.

According to a recent study by the National Science Foundation (2021), individuals working in science and engineering tend to earn higher salaries. In 2022, Malta’s gender pay gap persists and stands at 11.09% (OECD, 2023c). My study also found that the Maltese industry may not be well-equipped to accommodate a diverse range of genders, as males tend to prefer industry as a learning entity.

Interestingly, Lewenstein (2019) stated that his science communication courses are usually dominated by women, sometimes up to 90%. My study's PENs questionnaire revealed a majority of female respondents, consistent with trends identified during PEN interviews. Nevertheless, the data suggests that inadequate information about the network and high membership fees are key factors deterring a higher percentage of females from joining other PENs. On the other hand, males appear to be too busy to spare time for such networks or find them irrelevant. These results highlight gender disparities in STEM fields, which may further perpetuate the notion that science communication is a field dominated by females. This indicates that science communication is considered a less desirable career option with lower pay, status, and stability than scientific research. Communication is intertwined with the concept of care and support and is often perceived as a feminine attribute (Piatek-Jimenez et al., 2018). This belief further reinforces gender stereotypes and biases, which may have a significant impact on the overall societal perception of gender roles and expectations. This issue remains largely unaddressed despite being discussed in various conferences and classrooms (Lewenstein, 2019).

7.2.2 Researchers and scientists' challenges to engage publics

During my study, Maltese interviewees reported that a shortage of time, training, and funding, were significant factors that hindered scientists' and researchers' effectiveness in engaging citizens with science. These are common difficulties also expressed internationally (Dudo & Besley, 2016; Hamlyn et al., 2015; Mizumachi et al., 2011). Effective communication is often overlooked in certain fields, such as laboratory research work, where reaching a wider audience may not be considered a top priority. In Malta, interviewees indicated that their entities tend to rely on their current resources to manage communication needs in addition to their daily responsibilities, leading to insufficient attention being given to this important aspect.

7.2.2.1 Time

My study found that academics and researchers at UM have voiced their discontent with the inadequate acknowledgement of their endeavours in public outreach, which was also reflected in Levikov et al.'s (2020) study. This has resulted in a lopsided distribution of time and energy as they simultaneously fulfil responsibilities as educators, researchers, and communicators. The qualitative findings in Chapter 5 indicate that while UM acknowledges academics' efforts if they aspire to attain professor status, there is conflicting information on whether researchers' engagement activities are officially appreciated. Young academics appear to be more inclined towards public engagement as they believe it positively impacts the world. Therefore, a mix of intrinsic, extrinsic, formal, and informal incentives at higher educational institutions, as expressed by Hoffman, will encourage scientists and researchers to engage with various audiences and promote science (as cited in National Academy of Sciences, 2018). UM researcher interviewees indicated that staff involved in PES are primarily led by intrinsic motivation and informal incentives, but this is not a sustainable approach. Based on personal experience, guidance and encouragement can help scientists feel comfortable and willing to engage with citizens with limited expertise in the field. While not statistically significant, a local study on scientists' experiences with their engagement with informal dialogic events held by Malta Café Scientifique revealed that their initial hesitance was unnecessary, and they felt enthusiastic about discussing their research with the audience after the event (Farrugia, 2015).

7.2.2.2 Training

Scientists and researchers face challenges in effectively communicating with different audiences, which could be due to citizens' varying levels of misinformation, inadequate training, and missed opportunities. The complexity of understanding how misinformation manifests in individual citizens requires consideration of macro-level variables (Scheufele & Krause, 2019). Roche et al.'s (2023) findings suggest that a global perspective on science communication teaching can inform local practices, indicating that training programs should be tailored to address specific audience needs and misinformation challenges. To improve engagement, institutions should clarify expectations and provide continuous professional development to equip scientists and researchers with the necessary skills. Collaborations between artists and scientists can enrich interdisciplinary engagement. As seen in Malta's SITC festival (Qualia Analytics, 2023), collaboration between artists and scientists can benefit both fields. Such collaborations can offer fresh perspectives and creative approaches to scientific challenges. So, it is recommended that scientists explore interdisciplinary collaborations with artists. Similarly, while MCST offers various training opportunities, its explainers still need to be familiar with science to offer alternative ways of engagement both at the science centre and to encourage researchers to engage with different audiences. Moreover, the distribution of science communication teaching worldwide, as discussed by Massarani et al. (2023), highlights the importance of integrating diverse pedagogical strategies into training programmes.

7.2.2.3 Funding

My study found that funding is a critical aspect that both motivates and frustrates scientists and researchers (see Chapter 5). While it can encourage engagement with different publics, the lack of public funds available for research is a significant concern. The efficacy of allocating financial resources to advertise science centres on local television programs is a subject of inquiry that warrants careful consideration. One may wonder whether this approach is the most effective way to engage the public in scientific pursuits. My study indicated that MCAST and MEYR did not mention their need for funding. One plausible hypothesis could be posited that MCAST and MEYR may share the same fiscal resources and are already well-endowed with governmental funding, while the UM is comparatively under-resourced. The government's annual funding for the UM was cut by 1.1 million euros in August 2022, causing frustration among students and lecturers (Zammit, 2022). Moreover, the decreased funding for research makes it less likely for scientists and researchers to invest in engaging citizens. The situation is further exacerbated by the lack of funding for creating a holistic support system for science practitioners to engage publics, especially citizens. Despite the need for proper support and structure, lack of funding poses a significant challenge.

The diverse data collected throughout the research provides a comprehensive understanding of public engagement with science (PES) in the Maltese Islands, directly addressing the core research questions. Analysing structures, formats, policies, stakeholders, and relationships associated with PES reveals a fragmented landscape influenced by social dynamics such as gender, race, and class. This fragmentation aligns with the first research question, highlighting how these factors shape the interactions between various actors within the Maltese public sphere of science. Furthermore, insights into the goals and objectives of organisations conducting PES indicate a dual focus on educational outcomes and economic imperatives, thus answering the second question regarding underlying motivations. The data also reflects varying degrees of responsiveness to individual and societal needs, which is critical for evaluating the effectiveness of PES initiatives in Malta (research question three). Lastly, by comparing local practices with international science communication and education standards, the findings suggest potential pathways for integrating PES into a cohesive national strategy encompassing formal, informal, and non-formal dimensions of science education (research question four). Overall, this interconnected analysis underscores the necessity for a nuanced approach to PES that recognises both local contexts and broader international trends.

The connection between these empirical findings and theoretical frameworks is crucial; Bourdieu's theory of capital (1986) posits that individuals' engagement with science is influenced by their social and cultural capital, which can affect their perceptions and opportunities for participation in scientific discourse. Additionally, Habermas's concept of the public sphere (1973) underscores the importance of inclusive dialogue in fostering a knowledgeable citizenry capable of engaging with complex scientific issues.

7.3 The meeting of the formal with the informal

7.3.1 Science education and communication

Challenges faced by science educators and communication practitioners stem from a lack of communication and shared understanding of key terms (Lewenstein, 2015). While science educators prioritise education and engagement, communication practitioners prioritise entertainment and engagement, sometimes to the detriment of education (Baram-Tsabari & Osborne, 2015). Despite their shared goals and expertise, collaboration between the two fields is limited both locally and globally.

Educators and science communicators share the goal of teaching the next generation of scientists. However, while educators tend to focus on imparting rigorous scientific content, communication practitioners prioritise critical engagement. Ultimately, the struggle between the two fields is intensified by the very nature of science itself—how it is defined and what the scientific process entails (Chalmers, 2013; Nye, 2011; Lakatos & Feyerabend, 1999). My results showed that MCAST mentioned the importance of using the scientific method, indicating a traditional way of conceiving science and what is classified as 'scientific.' While not representative of the entire institution, this still indicates a view of a fixed way of defining how science is conducted.

The epistemological underpinnings that form the basis of the scientific method have been the subject of rigorous debate as they determine the methodologies and methods employed in scientific research (Bauer, 1992). These epistemological foundations also have a critical role in shaping worldviews and guiding the interpretation of results, contributing to the credibility and validity of scientific inquiry. The versions of the scientific method commonly taught to students fall short of capturing the complexity and nuances of the various scientific processes taking place (Bobrowsky, 2021). In reality, scientific inquiry involves a wide range of approaches and techniques and does not merely follow a predetermined set of steps (Bobrowsky, 2021).

Educators strive to incorporate inquiry-based education methodologies into their teaching both locally and globally (Constantinou et al., 2018). Additionally, science communication experts are actively engaged in conversations surrounding open schooling and open learning pedagogies, which allow for learning that is not confined by constraints such as timing, location, or instructional methods. As described by Make it Open (n.d.), this approach emphasises the importance of flexibility and accessibility in the learning process.

Science education in schools assumes that individuals can acquire the necessary knowledge to make informed and scientifically-based decisions based on science encountered in daily life (Baram-Tsabari & Osborne, 2015). Conversely, science communication suggests that people interpret science through various culturally relevant narratives, which may or may not include science, based on their prior knowledge (Feinstein, 2014; Laslo et al., 2011). The formal science curriculum should explore the type of knowledge that would benefit students and how it can be incorporated. Many public issues, such as measles, mumps, and rubella (MMR) vaccinations, genetically modified organisms (GMO) foods, or climate change, often present individuals with a binary decision between denial or unquestioning acceptance. To bridge the gap between the researcher and the citizen, it is my contention that formal education should aim to promote dialogue rather than simply providing more content knowledge.

Establishing spaces that can facilitate collaboration between science educators and communicators presents a unique opportunity for individuals with varying levels of expertise. To this end, my study aimed to investigate the effectiveness of PENs in increasing participation and identify the key factors that could enhance the engagement of members in these networks. The findings of the analysis suggested that the provision of useful services by PENs was the most significant factor in maintaining long-term involvement, accounting for 82.9% of the responses.

Effective science communication faces a significant hurdle - the divide between science communication academics and practitioners. Much like their STEM counterparts, science communication academics are not necessarily obligated to share their findings with practitioners in the field. Communication efforts are primarily focused on meeting funding requirements and generating publications. In academia, there has been a longstanding debate regarding the relationship between practice and research (Metcalfe, 2022). It is widely acknowledged that practice often moves faster than research, leading scholars to question the effectiveness of practical application. Conversely, practitioners have been known to question the relevance of research to their day-to-day work. As Metcalfe (2022) notes, this tension between practice and research has been a subject of ongoing discussion and analysis within the academic community. Based on experience, practitioners frequently find themselves without the time or expertise to adequately evaluate their events. In Malta, such as activities created by MEYR, evaluation is often overlooked, leaving organisers unsure whether the activity or event met its intended goals. Success is typically measured solely by the event happening. On the other hand, my study shows that, internationally, science communication scholars are not effectively communicating their research to science communication practitioners, which has been a topic of discussion in PENs. Additionally, science communication practitioners face difficulty encouraging STEM researchers to engage with citizens and communicate their work meaningfully.

In my view, several services, including assessment procedures, effective time management strategies, and facilitating communication between academics and science communication professionals, could greatly benefit individuals in the science communication community. However, my study showed that not all members of UM prioritise the pedagogical aspects of the continuous professional development (CPD) programme. To address this, training opportunities should be made accessible to all staff members. While some programs for doctoral students are also open to staff, certain topics, such as communicating with diverse audiences, should be mandatory to ensure professional growth. Additionally, structured training should be offered to all educational entities and Esplora, especially in the context of evaluating events and activities.

7.3.2 Democratisation of science of the Maltese PSS

The focus on professional development and training opportunities for staff members is just one aspect of promoting the democratisation of science, which involves increasing levels of engagement across various audiences.

Fig 7.1 shows the various levels of engagement of possible PES characterising the Maltese PSS. The diagram illustrates five distinct levels of public engagement, which should be considered as ranges. The largest group of publics, the *inactive and disengaged*, lie on the periphery in the diagram while the smallest group, the *empowered*, lie at the centre. Depending on the particular issue or topic, publics may exist within various levels of engagement. To exemplify, an individual who possesses a wealth of knowledge about materials may fall into the *involved* category, while they may be less informed about science education and therefore categorised as *receptive but disengaged.* The boundaries between the levels of engagement are depicted as dashed lines, indicating the potential for publics to transition from their current level of engagement to another. The font size of the levels of engagement and the size of the spirals correspond to the number of individuals within each level of engagement.

Applying Kuhn's philosophy, there was a time when publics unquestioningly accepted the use of public funds for scientific research, which he referred to as a period of "normal science" on a macro scale. However, based on my qualitative results (outlined in Chapter 5), I believe that citizens are now starting to question certain issues related to health, transportation, and the environment that they previously would not have questioned. During times of crisis, there are varying opinions within the scientific community regarding how publics should be engaged, with some favouring informative approaches and others preferring critical debate. These differing viewpoints can extend to the Maltese PSS and impact how citizens perceive and engage with scientific matters.

A central aspect of Kuhn's (1970) theory is the focus on the revolutionary nature of scientific advancement. This revolution entails the rejection of an existing theoretical framework in favour of a new, incompatible one. Another significant aspect is the critical role that the sociological characteristics of scientific communities play in this process. This contemplation has led me to develop a model that incorporates citizens' and publics' perspectives, involvement and participation with science and technology. Previously, participation was closely associated with the amount of science capital one could accumulate as highlighted in Archer et al's (2015) analysis, and the level of scientific literacy required (Miller, 1983) to be central in policy-making decisions. However, as opposed to Archer et al's (2015) understanding of the science capital, Bourdieu's interpretation of the capital of science is more nuanced, encompassing various forms of capital relative to an individual's habitus within the scientific field, while also recognising the power dynamics that influence participation in (PES) within the (PSS). By integrating the idealistic concept of Habermas's public sphere (1973) with Bourdieu's (1986) insight into the capital of science, we can better understand the different levels at which publics can engage depending on their various levels of expertise. The U.S.'s National Science Foundation's survey aimed to measure scientific literacy. An analysis of the historical progression of science and an evaluation of scientific literacy reveals distinct phases in comprehending scientific knowledge. An individual regarded as scientifically literate possesses a thorough understanding of scientific endeavours and the principles that underlie scientific inquiry. This understanding extends to the public's interest in science and their capacity to make informed decisions on significant public policy issues (Gastrow & Ishmael-Perkins, 2021; Bowater & Yeoman, 2013).

This classification of the different levels of engagement is inspired by the audience cluster grouping found in 2011's UK report, as well as my personal experience and primary data collected for this study (Department for Business Innovation and Skills, 2011). Below are the specific explanations of the five levels of engagement within the PSS.

Inactive and disengaged – Unwilling publics with little to no interest or involvement in science engagement activities due to limited exposure to science or feeling disconnected from scientific topics and discussions;

Receptive but Disengaged – Publics willing to engage in science under certain circumstances. They may attend public lectures, read popular science books or articles, or watch science-related programs;

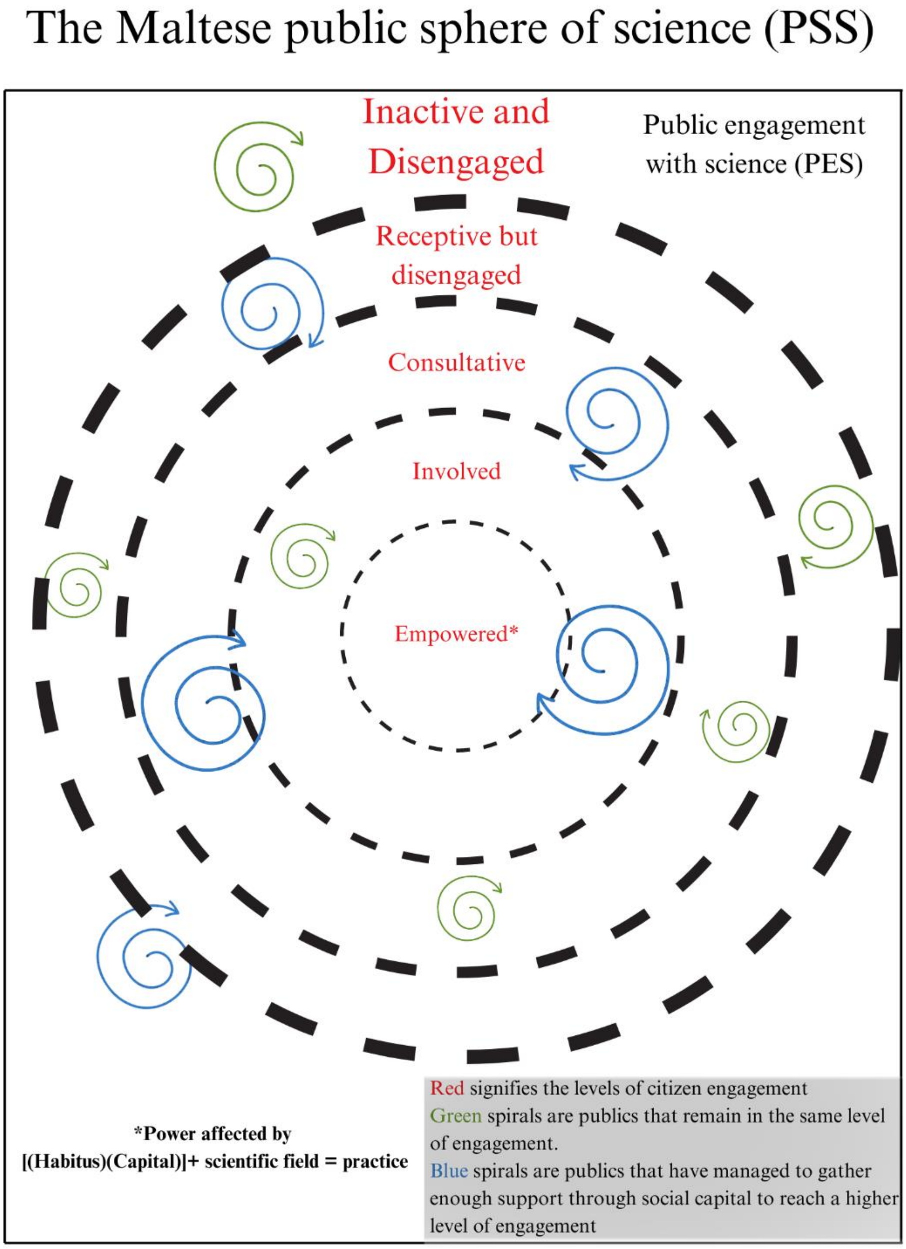
Consultative – Engaged publics but lacking specific scientific knowledge but provide input or feedback on scientific issues through surveys, focus groups, or public consultations;

Involved – Publics showing an active and sustained engagement with science, such as citizen science projects, and contribute to the generation or analysis of scientific data;

Empowered – Publics who actively engage in shaping scientific agendas, policies or practices. They may advocate for science-related issues, participate in science policy discussions, or collaborate with scientists and policymakers to address societal challenges.

Figure 7.1:

The Maltese PSS



At each level of scientific engagement, certain publics engage in science progressively and build their expertise in science but remain within the same level of engagement, represented by the green spirals.

However, other publics are able to accumulate enough scientific capital to move up to the next level of engagement when favourable conditions arise, represented by the blue spirals. The spirals symbolise the non-linear progression that publics may undergo if they choose to transition from their current level of engagement. According to Kuhn's philosophy, those who remain within their level of engagement remain in the normal or crisis phases. Meanwhile, those publics in the blue spiral who possess the necessary social capital are able to ascend to a higher level of engagement, initiating a revolution and causing a paradigm shift away from the dominant scientific paradigm.

The diagram in Figure 7.1 incorporates Bourdieu's formula (adapted to the scientific field) that accounts for the publics' capital of science in their PES within the PSS. The formula states that [(habitus)(capital)] + scientific field = practice (Bourdieu, 1984, p.101). The educational system plays an important role in reproducing cultural arbitrariness (Bourdieu & Passeron, 2014), However, it does not guarantee access to the highest level of decision-making in defining what science is. The role of power struggles that perpetuate and reproduce the status quo, as implied in Figure 7.1, is not mentioned in Archer's science capital. This is portrayed in the figure by the publics who are stuck in the blue spirals due to lack of gathering the right kind of capital. Inadequate attention to power dynamics within the scientific community and their influence on science engagement is also lacking in Archer's and colleagues' analysis (Jensen & Wright, 2015). Archer's concept of science capital does not address the mechanisms through which the dimensions of capital influence citizens' participation through the role of institutional power perpetuated by educational entities. This analysis included in-depth data on senior management of local entities to provide further insights on the interplay of who gets to make decisions on who to engage in the Maltese PSS. This, in fact, aligns more with the capital of science as it acknowledges the power that entities yield in who gets to engage.

Based on my results and experience, scientific resources, knowledge, and networks are not equally accessible to all groups, resulting in privileged publics maintaining their status. This creates an uneven playing field for publics seeking to engage with science. Dewey's philosophy suggests that every problem can create its own group of individuals, with each group usually having different members but with overlapping memberships (Cutchin, 2020). Access to science is often limited to those with specific credentials, funding, and publication opportunities, thus creating barriers to entry for many individuals. My research discovered that the most prevalent capital is the relevant social capital that is accrued by individuals and entities. The centre represents the highest tier of engagement, which is still largely reserved for those with established connections to influential individuals. Additionally, the concept of islandness, prevalent in local communities, can further exacerbate exclusivity (Baldacchino, 1993, 2007). In the context of the diagram, the concept of "islandness" is articulated through the significant influence of social capital, which results from the country's size and therefore smaller populations within each level of engagement. This dynamic contributes to the entrenchment of populations within blue spirals, reflecting the limitations and challenges faced by these communities. This leads to individuals, publics, and entities being excluded based on factors such as one's socioeconomic status or cultural background. While social capital can play a significant role in shaping social cohesion, resilience and collection action, it also limits diversity and discourages implementing new ideas that may lead to stagnation or missed opportunities. On the other hand, in my view, entities such as schools, government bodies, and the media have the power to shape public opinion, which can impact individuals' willingness to engage in scientific endeavours.

John Dewey's democratic theory stresses the importance of inclusive and informed citizen participation in shaping collective decisions and policies (Feinstein, 2015). According to Dewey, continuous dialogue and collaboration between diverse groups and communities are essential for a thriving democracy. In agreement with Dewey, a dynamic democracy requires the involvement of a broad spectrum of stakeholders to ensure its longevity and advancement. In addressing social and political challenges, the significance of democratic participation and civic engagement can lead to developing critical consciousness among citizens (Cutchin, 2020). Similarly, Paulo Freire's pedagogical approach can serve science education and communication to develop citizens' critical consciousness and encourage active participation in transforming their social reality (Freire, 2014). The analysis of the results, and my experience as a science communication practitioner, the adoption of Freire's pedagogical approach is a crucial step that requires a paradigm shift in the current educational landscape. Such a shift must be anchored in a value system that aligns with the foundational principles espoused by Dewey, which emphasise the importance of experiential learning, democratic participation, and, later on, active engagement with society.

The capital of science should be linked to learning how to be a critical citizen by questioning the status quo. This approach can empower citizens to increase their relevant social capital and make social structures more equitable for all. On the other hand, while certification, funding, and publications play a crucial role in the production of scientific knowledge, Einsiedel (2014) argues that citizens who do not have access to such resources can still contribute to the production of knowledge with their experiences and capacities related to scientific debates, new technologies or social problems. Therefore, it is crucial to consider the perspectives of all citizens, including the *inactive and disengaged*, in producing scientific knowledge.

Dialogic approaches, which emphasise open communication, have been identified as effective strategies for increasing participation levels in decision-making processes. This is evidenced by Hart's Ladder (Hart, 1992), which outlines a progression from tokenism to genuine participation, with open dialogue being a critical factor in reaching higher rungs of the ladder. Furthermore, citizen science projects represent the pinnacle of engagement, providing citizens with agency, control, and power. The rapid progress of citizen science research, fueled by the active participation of citizens and advancements in technology, presents compelling evidence of the potential for citizen science to emerge as a distinct discipline that can enhance and democratise the scientific inquiry process (Hajibayova, 2020). However, in my contention, it is important to note that citizen science projects can offer various levels of engagement, and it is crucial to avoid tokenistic approaches.

It is imperative for researchers to exercise caution when seeking data samples from citizens without meaningful compensation, as this approach can be viewed as tokenistic, and can hinder the potential for meaningful, interactive, and collaborative citizen involvement in scientific research. I believe that a more democratic and participatory approach must be adopted to enhance the relevance and societal impact of scientific research. Eko-skola provides an exemplary model to demonstrate how young students under 16 can develop their projects with the help of their educators, even at such a tender age (Pace, 2007). This indicates that if such high levels of engagement are feasible with children, *inactive and disengaged* citizens can also contribute meaningfully to society.

Lundy's model of participation (Lundy, 2007), originally designed to empower children to engage, can be applied to older citizens as well. It is worth considering that policy-makers often view children as incapable of contributing to 'serious' issues. Similarly, those who hold positions of power in public engagement may perceive citizens in lower levels of engagement as lacking the necessary capital, whether it be scientific expertise or social capital, to make meaningful contributions to a specific cause. This perception often leads to a disparity in the publics' ability to contribute to the decision-making process, perpetuating inequalities in society. Lundy's adapted model can offer the space for citizens to express their views freely and participate as part of long-term involvement or a one-off event.

The question remains of how entities and organisations empower citizens to engage. I explored educational models, particularly Lundy's model, which has garnered significant attention for its representation of a paradigm shift towards recognising children as active agents in society rather than passive recipients needing care and protection. My interest in this model stems from the fact that children are often overlooked and denied the opportunity to contribute as a segment of society. Furthermore, individuals who are disinterested or lack substantial knowledge of science can be compared to how children are typically perceived in society. Lundy's framework outlines four elements designed to empower citizens, enhancing their relevant capital and facilitating access to higher levels of engagement, as illustrated by the blue spirals in Figure 7.1.

Figure 7.2 uses Lundy's four elements to empower citizens to increase their relevant capital and gain access to higher levels of engagement (represented by the blue spirals) in Figure 7.1. The figure illustrates how entities can encourage and empower publics' relevant capital (represented as a seed) to engage in PES following a sequential process of Space, Voice, Audience, and Influence (SVAI) (represented as the soil). Bucchi and Trench's model (2021) also highlights the importance of dialogic and participatory approaches as the highest forms of engagement which could serve as platforms to conduct meaningful engagement using the SVAI approach. Similar to flowers that flourish under favourable conditions, citizens are empowered by entities to distinguish between disinformation and misinformation and evaluate them accordingly. A National Strategy for Public Engagement with Science and Technology (NPEST) inclusive of various stakeholders, such as the National STEM engagement group, could nurture publics' SVAI approach with the relevant governance and policy (represented as nutrients) from entities for the seed to keep growing and reach its full potential (signified as the last stage when the plant reaches maturity and is ready to make other seeds).

1. Space: Provide a safe and inclusive space for publics to express their views

    - Have publics' views been actively sought? (e.g. through dialogue sessions, consultations, and others)

    - Was there a safe space in which publics could express themselves freely? (Not only in educational institutions for example which would exclude publics who had negative experiences with formal education)

    - Have steps been taken to ensure that all publics can take part? (issues related to accessibility)

2. **Voice: Provide appropriate information and facilitate the expression of publics' views**

    - Have publics been given the information they need to form a view? (Related to dissemination of information)

    - Do publics know that participation is voluntary?

    - Have publics been given a range of options for how they might express themselves? (Through dialogue, social media platforms, events, festivals etc.)

3. **Audience: Ensure that publics' views are communicated to someone with the responsibility to listen**

    - Is there a process for communicating publics' views?

    - Do publics know who their views are being communicated to? (Who is the mediator?)

    - Does that person/body have the power to make decisions? (Are they talking to a policymaker?)

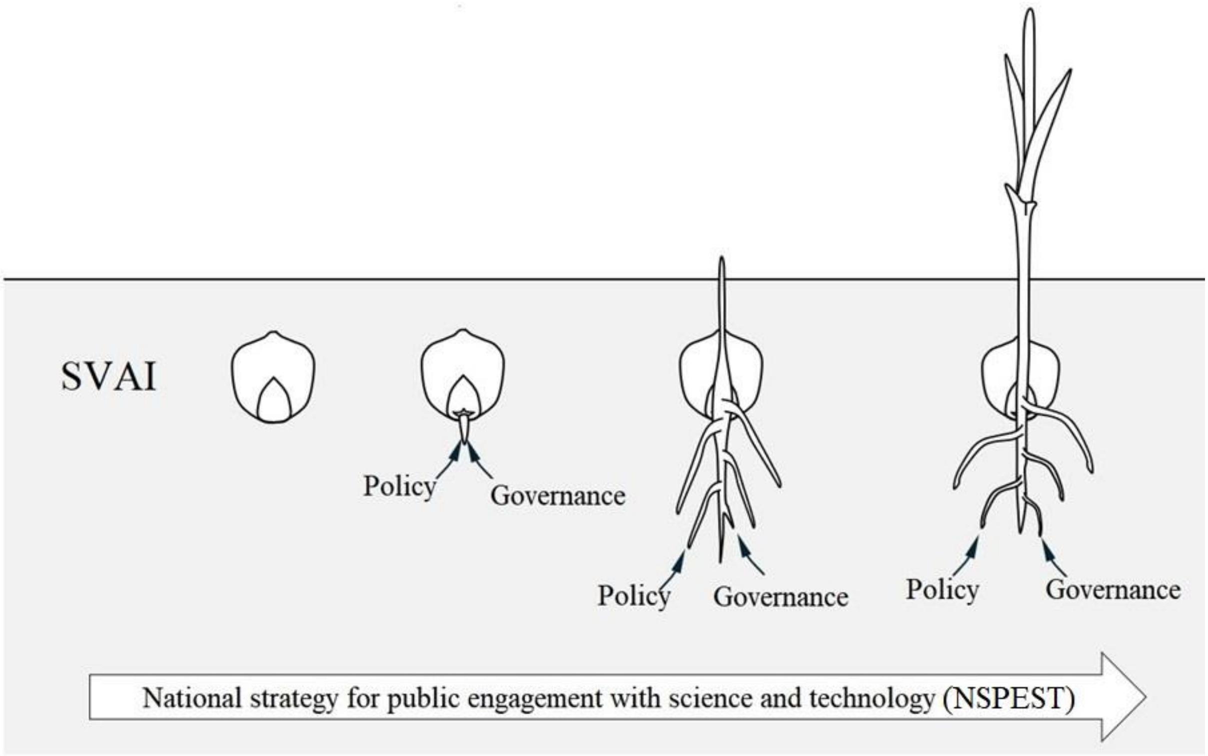
4. **Influence: Ensure that publics' views are taken seriously and acted upon where appropriate**

    - Were publics' views considered by those with the power to effect change? (e.g. policymakers, politicians)

- Are there procedures in place that ensure that the publics' views have been taken seriously?
- Have the publics been provided with feedback explaining the reasons for decisions taken?

Figure 7.2:

Entities empowering publics to increase their capital for meaningful PES.



7.4 A way forward to a unified approach – breaking the hegemony and shifting paradigms

Much like in ecosystems in nature, the ability to access the inner circle of Figure 7.1 is determined by factors such as seasonality, habitat changes and competition. While some individuals are born with these connections, others must build their social capital through political means.

This doctorate proposes a paradigm shift in the PSS, following Kuhn's ideas, which encourages PES in various forms and at various levels. Acknowledging that citizens who do not aspire to STEM careers can still make valuable contributions to scientific knowledge development will encourage interdisciplinary collaboration and bridge gaps between different scientific paradigms. An open-minded approach within the scientific community to consider alternative perspectives will help prevent dogmatism and facilitate the exploration of new ideas. In practical terms, citizens and NGOs can act as intermediaries in projects and exhibitions, allowing for greater citizen involvement. Providing more opportunities for citizens to engage in science-related discussions, will provide a safe space for dialogue and help dispel misconceptions, misinformation and disinformation.

In my view, investment in human resources, from formal science educators to informal and non-formal science practitioners, is necessary to ensure that audiences are understood and given the space and voice to be critical citizens in society. Furthermore, science practitioners need time and resources to learn how to evaluate their events. Strengthening communication between science practitioners and social sciences researchers could be achieved through a national PEN. A national strategy for PES (NPEST) could give some much-needed structure, with the national PEN acting to create the appropriate governance and policy to move towards citizens being critically engaged and involved at various levels of PES in the PSS.

The next and final chapter delves into a path forward and presents various recommendations and research areas aimed at mitigating current fragmentation and moving beyond the dominant hegemonic paradigm.

Chapter 8

Conclusion:
A way forward

8.0 Introduction

The thesis significantly contributes to the fields of science communication and public engagement with science by critically analysing the complexities of the Maltese public sphere of science (PSS). By employing an intersectionality framework, it reveals how social structures—such as gender, race, and class—impact citizens' scientific identities and their engagement levels. Drawing from Habermas's concept of the public sphere, the research highlights the power dynamics that shape public engagement, illustrating how inequalities and fragmentation within PES contribute to citizens' disengagement from science (Habermas, 1973). Furthermore, the thesis integrates Bourdieu's framework on capital to elucidate how access to scientific knowledge is mediated by social and cultural capital, which significantly influences individuals' ability to engage with science (Bourdieu, 1986). Archer et al. (2015) indicated that low socioeconomic status is often linked to low science capital, suggesting that families with limited resources are less likely to pursue scientific interests beyond formal education. This underscores the necessity for PES initiatives to not only disseminate knowledge but also actively dismantle barriers related to socioeconomic inequalities. Additionally, the research applies Kuhn's concept of paradigm shifts to advocate for transformative changes in how PES is conceptualised and implemented (Kuhn, 1970). It calls for a reevaluation of existing frameworks and practices in PES, emphasising strategies that empower marginalised communities and recognise the diverse experiences shaping individuals' relationships with science. By addressing systemic inequities within the Maltese PSS, this thesis not only enriches theoretical discussions but also provides actionable insights for policymakers and practitioners aiming to enhance public engagement with science in Malta and beyond.

8.1 Main findings from this study

My research findings from the questionnaire given to Maltese residents indicate that most of the Maltese population (80.2%) held a keen interest in science, regardless of age. However, there was a slight decline in interest observed among the 55-64 age group. Furthermore, the study revealed that individuals with undergraduate and postgraduate degrees displayed the highest attendance at science-related activities. At the same time, those with a primary or secondary education background showed the lowest attendance. In terms of age groups, the highest percentage of attendees belonged to the 18-24 group. The lowest attendance was observed among the 55-64 and 65+ age groups.

From the interviews conducted for my study, all the entities in Malta indicated a shared commitment to engaging a diverse range of stakeholders with science through both formal and informal channels. However, the specific type and focus of engagement varied depending on each entity's priorities and vision. It was noted that informal science education and engagement are currently fragmented and lack a cohesive strategy. As such, there is a need for collaboration and developing a common approach.

The findings of my international quantitative questionnaire revealed some noteworthy highlights. It was observed that the members of PENs tend to contribute more in terms of time, knowledge, stakeholder contacts, mentoring, and writing proposals rather than financially. Moreover, the existing financial contributions made by the members to the PEN were found to be aligned with their financial capabilities. The respondents perceived PEN as an effective network in terms of its structure, management, communication, and participation. However, my results showed that respondents tend not to join other PENs due to high membership fees and a lack of information about the network. My study found that larger percentages of males feel too busy and lack relevance in joining other PENs. In comparison, larger percentages of females feel that lack of information about the network and high membership fees are the main reasons for not joining other PENs. Lastly, the international questionnaire reported that the primary reasons for members staying in a PEN for the long term were useful services and effective leadership.

Based on my international qualitative findings, results suggest that PEN management faced challenges handling their full-time jobs while fulfilling these duties, resulting in adopting different leadership styles. Most networks' leadership styles reflected commitment, trust, openness, and collaboration. The senior management's main priorities were to provide valuable services to their members, remain relevant, and ensure the PEN's survival and sustainability. While governance policies can aid in sustainability, securing the required resources is the primary challenge for the network to prosper. The funding sources for PENs included membership fees, EU project funds, grants from foundations, sponsorship for specific activities such as conferences, and personal funds. Opinions varied among PENs regarding membership, with some prioritising increasing their membership base, whereas others prioritising quality over quantity due to financial considerations. Nonetheless, all PENs strive to remain relevant, which can be daunting, and maintaining their current membership numbers is a significant concern.

8.2 Contribution to knowledge in science education and communication

My doctoral research, through the lens of intersectionality, delved into the power dynamics within the Maltese PSS, examining how inequalities and fragmentation emerge from the dominant understanding of what constitutes science in PES. The findings, depicted in Figure 7.1, reveal the correlation between this notion and citizens' disengagement with science. Additionally, the study uncovers the intricate biases and complexities embedded in the construction of scientific knowledge and their impact on PES.

The publics on the outskirts with minimal access are the least involved, while the empowered are found in the centre and have access to being the most involved in PES. Depending on the topic at hand, publics may exist at various levels of engagement. The highest level of engagement related to decision-making is reserved for the few. Applying Bourdieu's theory of capital, individuals or groups must possess sufficient cultural, social, economic, or symbolic capital to progress to higher levels of engagement. For the Maltese Islands, social capital is particularly crucial for accessing the upper echelons of engagement. Those who fail to accumulate sufficient capital remain at their current level of engagement. This framework can be used to interpret the dynamics of the public sphere of science in other countries, at either the micro or macro level, as well as to explore the relationships between stakeholders, entities, and publics.

Acknowledging the power that both individuals and entities wield in who gains access to the highest level of engagement, citizen empowerment by entities can only flourish if publics are aware of how to gain capital with the right nutrients potentially implemented as part of a national strategy with the adequate governance and policy. The right nutrients (based on Lundy's model of participation, (2007)) mean that publics need to be given a safe and inclusive space to express their views, provide appropriate information and facilitate the expression of public views. Furthermore, the publics' views are communicated to someone who is responsible for listening and ensuring that their views are taken seriously and acted upon. This will assist with the inequalities arising from the publics' lack of engagement and ability to effect change.

8.3 Further research and recommendations

For the Maltese Islands, I recommend that the National STEM engagement group develop a comprehensive strategy for guiding governance and policy. The strategy needs to reflect Habermas's (1973-1974) concept of the public sphere, which emphasises the importance of inclusive dialogue among diverse stakeholders. This plan should involve extensive consultations with stakeholders, utilising a hybrid methodology that combines both top-down and bottom-up approaches. The intersectionality framework is crucial for analysing how various social identities—such as gender, race, and class—interact to shape individuals' experiences with science. The data indicates that these identities significantly influence citizens' scientific identities and their engagement levels, thus highlighting the need for policies that address these intersecting factors (Crenshaw, 1989). As illustrated in Figure 7.2, leveraging Lundy's model adapted to publics empowers publics to have a say, a platform, and an impact in driving change. However, without ensuring Space, Voice, Audience and Identity (SVAI) and implementing suitable governance and policy measures, this plan will merely be another document gathering dust. Kuhn's (1970) concept of paradigm shifts emphasises that significant changes in scientific understanding often arise from the integration of diverse perspectives and disciplines, leading to new frameworks for interpreting scientific phenomena. This aligns with the proposed PES space's vision to foster transdisciplinary research, which inherently requires collaboration across various fields and expertise. In addition, establishing a national PES space, whether in the form of a network, hub, platform, or centre, could provide valuable services to science communication practitioners who collaborate with NGOs, educational institutions, and government entities to engage science communication practitioners. Short-and long-term non-formal courses can facilitate this connection. Furthermore, this space has the potential to consolidate specialised areas and reduce current fragmentation. Lessons learned from my study showed that a solid funding stream is required for the PES space to endure. Ideally, such a space would be independently run, but securing solid funding can be a significant obstacle. Therefore, it may be necessary for the PES space to be incorporated into a centre at a university or a hub at a science centre. This would allow full-time employees to oversee the space's operations, ensuring smooth functioning and providing necessary services. Other positions could be filled on a voluntary basis.

The PES's space vision could be to create a shared understanding of the importance of transdisciplinary research and approaches to PES through collaborations with staff, researchers, and students from different entities, NGOs, industry, the media, and society. It can also aim to coordinate public engagement with science activities, research, and initiatives by attracting funding, students, and international collaborations to improve their impact on society. Training would also support researchers in engaging other stakeholders, attracting national and EU-based funding, and effectively communicating their research locally and internationally.

Since results from members of international PENs showed that services are one major reason for signing up and remaining in a PEN, such a space needs to provide useful services for its members. Science communication practitioners working in both entities and NGOs will have the opportunity to attend local and international courses. The courses will cover various topics such as effective communication with diverse audiences, event planning and evaluation, writing for different audiences, social media use in science communication, and creative audience engagement strategies. Ideally, the courses will be available locally through educational entities, science centres, or international collaborations. Other services include applying for funds, empowering students to conduct community based research, citizen science opportunities and space for people to meet and work together. Additionally, the PES space could provide a platform for journalists who want to specialise in science communication.

Another recommendation is that entities establish clear aims and visions prior to commencing any initiative or event and implement a system of ongoing evaluation to ensure the attainment of these objectives. By doing so, entities (or NGOs) can significantly enhance their chances of achieving their desired outcomes in future activities.

An intriguing domain that demands further scholarly investigation is the manifestation of science communication in local media. It is imperative to scrutinise the nature of the content being generated and the function it performs in tackling disinformation and misinformation. Furthermore, comprehending the degree of media literacy in society is of paramount significance since it directly affects how media, particularly social media, distorts information in the PSS. Further research could delve into the evaluation of specific occurrences in this context.

The outcome of my research has been quite insightful, as it has brought to the fore the existence of PES fragmentation at diverse levels of society within the PSS and the entities involved in PES. This fragmentation appears to be deeply ingrained in a cultural system of proximity due to islandness, with the notion of hegemonic power (Badino and Omodeo (2021) and its consequential unequal access to and justification of power over time.

In conclusion, the recommendations outlined are not merely practical suggestions but are firmly rooted in established theoretical frameworks that advocate for inclusive dialogue, collaboration, and systematic evaluation. This mixed-method research has highlighted the need for a more cohesive and integrated approach to science communication in the Maltese Islands. The findings suggest that there is a shared commitment among entities to engage with a diverse range of stakeholders. However, there is a lack of a common approach and fragmentation in informal science education and engagement. The international findings suggest that effective leadership, useful services, and the financial capabilities of members are key factors in the sustainability of PENs. Moving forward, it is recommended that the entities involved in science communication in Malta work together to develop a common strategy and approach that can address the existing fragmentation and ensure a more coordinated effort towards engaging publics with science as illustrated in Figure 7.2 to break away from the hegemony and shift paradigms.

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Appendices

Appendix 1

Ethics approval

UNIQUE FORM ID: 2732_04072019_Danielle Martine Farrugia

No self-assessment issues ticked. Submitting to FREC for records.

L-Università ta' Malta

ETHICS & DATA PROTECTION

PART 1: APPLICANT AND PROJECT DETAILS

1. Name and surname: Danielle Martine Farrugia
2. Applicant status: UM student
3. Faculty: Education
4. Department: Mathematics and Science Education

    If applicable

    5. Principal supervisor's name: Prof. Paul Pace
    6. Co-supervisor's name: Prof. Alexander Gerber and Dr Edward Duca
    7. Study-unit code: Master of Philosophy in Education
    8. Student number: 05032815

9. Title of research project: Towards a National Strategy for Public Engagement with Science.
10. Research question/statement & method: Research Questions

1) What are the specific structures, formats, policies, stakeholders, actors and relationships associated with public engagement with science in Malta?
2) What are the underlying goals and objectives of the organisations and institutions that perform public engagement with science in Malta?
3) To what extent does public engagement with science in Malta respond effectively to individual and societal needs?
4) To what extent could a national strategy for public engagement with science integrate science communication with the different dimensions of science education (i.e. formal, informal, non-formal)?

Data Collection:

Data will be generated by adopting a mixed method approach.
Thematic analysis of policy/framework/strategy documents will be conducted to identify common and prevalent themes with respect to science communication, and more specifically to public engagement with science. These themes will be used to create semi-structured interviews with key policy makers and senior employees of institutions from different geographical regions. These interviews will look into the process of policy making and the involvement of various stakeholders in the process of public engagement with science in different countries, including Malta. The selection of potential interview candidates will be made from available lists of senior members within research institutions and policy-making organisations and government, keeping a diverse geographical spread.
A survey will be distributed within governmental institutions (targeting employees) and non-governmental institutions (targeting employees and volunteers). Cluster sampling will be used when distributing the survey to governmental and non-governmental institutions. Depending on the size of the institution, senior members will be identified through an online search and contacted through e-mails. Systematic sampling will be used to collect data from citizens. Approximately 6 interviews will be conducted from approximately

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No self-assessment issues ticked. Submitting to FREC for records.

10 institutions.
A short questionnaire will be designed for civil society. Data will be collected from various cultural, local, scientific (such as a science festival) and non-scientific events. Systematic sampling will be conducted whereby, the 10th person over the age of 18 will be identified and asked to participate. In order to capture a different cohort of civil society, an online version of the survey will also be created and distributed through mailing lists and social media.
All the surveys developed will be pretested to make sure that the questions are understood by the intended respondents. The data generated from the surveys will inform the themes addressed during focus group sessions. Four group sessions will be held, after identifying the interest from the stakeholders mentioned above and their willingness to contribute to the study. The questions to the focus groups will be forwarded at a later stage as these will be designed based on the previous data collection.

11. Collection of primary data from human participants?
Yes/Unsure (PLEASE ANSWER NEXT QUESTION)
12. If applicable, explain: a. salient characteristics (min-max participants, age, sex, other); Age: Over 18, Sex: Representative sample from each gender group. Civil Society approximately around 200. Institutions: approximately 8 participants from each institution. Science communication networks: Approximately 20 interviews. Science policy makers/research institutions participants: approximately 21 interviews.
b. how they will be recruited; A brief introduction about the project will be given to potential participants and their consent sought. Participants for interviews will be on a voluntary basis through an online search and attending conferences. For citizen surveys, random sampling will be applied. Information about the survey will be given and their consent sought for. The citizen survey will also be sent through online media to gather as many responses as possible. Since the interview guide still needs to be created for the focus groups, recruitment procedure will be designed after the initial data collection has been conducted.
c. what they will be required to do; participate in interviews/surveys/focus groups. The interviews and focus groups will be recorded. The speed of the recording will be changed so that the voices are not easily identified and the file will be saved with a pseudo name. For citizen surveys, the citizens will be asked to answer a short questionnaire on a voluntary basis. Responses will be anonymised.
d. duration; citizen surveys will be short (around 15 minutes), semi-structured interviews with key stakeholders of institutions will be approximately 1 hour. Focus groups will take around an hour
e. if inducements/rewards/compensation are offered; no rewards will be offered to entice participation
f. how participants may benefit. Participants will not benefit directly but remotely from the study as they will be providing insights on how the strategy can be inclusive of various stakeholders hence be effective to all of society.

PART 2: SELF-ASSESSMENT

Human Participants

1. Risk of harm to participants:
2. Physical intervention:
3. Vulnerable participants:
4. Identifiable participants:

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No self-assessment issues ticked. Submitting to FREC for records.

5. Special Categories of Personal Data (SCPD):
6. Human tissue/samples:
7. Withheld info assent/consent:
8. Opt-out at consent/assent:
9. Deception in data generation:
10. Incidental findings:

Unpublished secondary data

11. Was the data collected from human participants?
12. Was the data collected from animals?
13. Is written permission from the data controller still to be obtained?

Animals

14. Live animals out of habitat:
15. Live animals, risk of harm:
16. Dead animals, illegal:

General considerations

17. Cooperating institution:
18. Risk to researcher/s:
19. Risk to environment:
20. Commercial sensitivity
21. Other potential risks:

Self-assessment outcome: No self-assessment issues ticked. Submitting to FREC for records.

PART 3: DETAILED ASSESSMENT

1. Risk of harm to participants:
2. Physical intervention on participants:
3. Vulnerable participants:
4. Identifiable participants:
5. Special Categories of Personal Data (sensitive personal data):
6. Collection of human tissue/samples:
7. Withholding information at consent/assent:
8. Opt-out at consent/assent:
9. Deception in data generation:
10. Incidental findings:
11. Unpublished secondary data - human participants :
12. Unpublished secondary data - animals:
13. Unpublished secondary data - no written permission from data controller:
14. Lasting harm to animals out of natural habitat:

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No self-assessment issues ticked. Submitting to FREC for records.

15. Risk of harm to live animals :
16. Use of non legal animals/tissue:
17. Permission from cooperating institution:
18. Risk to researcher/team:
19. Risk of harm to environment:
20. Commercial sensitivity:
21. Other issues
    - 21a. Dual use and/or misuse:
    - 21b. Conflict of Interest:
    - 21c. Dual role:
    - 21d. Use research tools:
    - 21e. Collaboration/data/material collection in low/lower-middle income country:
    - 21f. Import/export of records/data/materials/specimens:
    - 21g. Harvest of data from social media:
    - 21h. Other considerations:

PART 4: SUBMISSION

1. Which FREC are you submitting to? : Education
2. Attachments: Information and recruitment letter*, Consent forms (adult participants)*, Data collection tools (interview questions, questionnaire etc.)
3. Cover note for FREC :
4. Declarations: I hereby confirm having read the University of Malta Research Code of Practice and the University of Malta Research Ethics Review Procedures., I hereby confirm that the answers to the questions above reflect the contents of the research proposal and that the information provided above is truthful., I hereby give consent to the University Research Ethics Committee to process my personal data for the purpose of evaluating my request, audit and other matters related to this application. I understand that I have a right of access to my personal data and to obtain the rectification, erasure or restriction of processing in accordance with data protection law and in particular the General Data Protection Regulation (EU 2016/679, repealing Directive 95/46/EC) and national legislation that implements and further specifies the relevant provisions of said Regulation.
5. Applicant Signature: Danielle Martine Farrugia
6. Date of submission: 04072019
7. If applicable data collection start date: 11072019
8. E-mail address (Applicant): danielle.m.farrugia@um.edu.mt
9. E-mail address (Principal supervisor): paul.j.pace@um.edu.mt
10. Conclude: Proceed to Submission

Appendix 2

Information sheet, consent form, and local questionnaire

Evaluation Participation

The following information will help to inform you about why you are being asked to take part in a survey and what happens to the information you provide.

How much time is needed to participate? You have given your consent to fill in a survey that approximately takes around **10 minutes** to complete. However, you may withdraw from participating in this research at any time and for any reason.

What happens to the information I provide? By providing your consent to participate you have agreed that your responses will only be used for research and evaluation purposes, within Danielle Martine Farrugia's doctoral studies at the University of Malta. The studies will provide a better understanding of the current trends in science and in how citizens and other major stakeholders are engaging with science.

Research reports or publications will not include your name or any personal association with quotations or reported statistics. Furthermore, your personal information will be kept confidential and your responses will not be quoted in marketing materials unless you provide explicit consent.

Agreement to Participate

Please read the following statements below:

- My responses will be used for research and evaluation purposes only. Also, my personal information will only be used for these purposes.
- When my responses are used for reporting or publication, my identifiable personal information will be removed from quotations or reported statistics.
- The information I provide about myself is confidential. My identity will not be disclosed to a third party or made public. This may require replacing my name with a pseudonym to protect my identity.
- My participation is voluntary, and I can withdraw at any time.
- I have received adequate information about my participation in this study and understand what will happen to the information I provide.

If you do not agree with any of the statements above, or would like clarification, please advise or send an e- mail on

Science Citizen Survey

Consent

I have understood the information provided in the information sheet and I'm willing to participate in this study by filling in this survey.

Section 1: General information
1) Age___
2) Gender *Options:* Female/Male/Other
3) Nationality: ____________
4) Current Hometown: ___________
5) Highest Education Qualification: *Options:* Primary, Secondary, Sixth form, Diploma, Undergraduate degree, Post graduate degree, Prefer not to say
6a) Are you a member of any organisation (e.g. Friends of the Earth, Greenhouse, Action for Breast Cancer Foundation)? *Options*: Yes/No/Prefer not to say
6b) **If yes - Which organisations are you a member of? If not please write N/A (Open-ended question)**
6c) If Yes: Follow up question: What is your role within this organisation? Options: Administration, Active member, Member but not active, Senior member, Not a member, Other (please specify)

Section 2: Attitude towards science
7) What 3 words come to mind when you hear the word 'Science'?
8) Are you interested in science? Yes/No/ I do not know/Prefer not to say
8a) If yes, which aspects of science interest you? If not please write N/A (Open-Ended Question)
9) Have you ever worked in the science related field?

Options: Yes, I currently work in a science related field, Yes but not anymore, No, I do not currently work in a science related field, No, I have never worked in a science related field, Prefer not to say

Section 3: Level of engagement with science
10) Do you attend any activities/events related to science? *Options:* Yes/No/I do not know
11a) How frequently have you attended science centres/museums and science festivals? Options: (Matrix Choice) Esplora, Life Sciences park, Malta national aquarium, National Museum of Natural History, Malta Maritime Museum, Science in the City, Science in the Citadel,Other please specify
Every year, Whenever I have time, Once, Never, Not Aware of centre/festival, Prefer not to say
11b) How frequently have you attended events organised by non-governmental organisations (NGO's), over the past year? Options: Matrix Style
CineXjenza, Café Scientifique Gozo, Malta Café Scientifique, Kids Dig Science, Other (Please specify)
Every event, Whenever I have time, Once, Never, Not aware of NGO, Prefer not to say
12a) I prefer learning about science developments and research through:
Options **:**Likert Scale Strongly Agree to Strongly Disagree (Matrix Style) and Prefer not to say

Internet, Newspapers, TV, Radio, Podcasts, Blogs, Science events, Other (Please specify).
12b) I prefer learning about science developments and research from:
Options: Likert Scale Strongly Agree to Strongly Disagree (Matrix Style) and Prefer not to say
Government (e.g. Ministry for Education and Employment), Malta Council for Science and Technology (MCST) (e.g. Esplora), Non-governmental organisations (e.g. Birdlife & Astronomical society of Malta), Media (e.g. PBS), University of Malta, Malta College of Arts, Science and Technology (MCAST), Industry, Other (Please specify).
13) How well informed do you feel about science, technology and innovation?
Options**:** Likert Scale
Extremely well informed, Informed, Neutral, Not informed, Extremely uninformed, I do not know

Questions in Maltese

Jiena fhimt l-informazzjoni li ġiet provduta lili u lest/a li nipparteċipa f'dan l-studju billi nimla dan s-survey.

1) Eta'
2) Sess – Femminil, Maskil, Other
3) Nazzjonalita'
4) Fejn qiegħed toqgħod bħalissa
5) L-iktar kwalifika għolja ta l-edukazzjoni - *Primarja, Sekondarja, Sixth form, Diploma, Undergraduate degree, Post graduate degree, Nipreferi ma ngħidx*
6) 6a) Inti membru ta xi organizazzjoni? (e.g. Friends of the Earth, Greenhouse, Action for Breast Cancer Foundation)? *Iva, Le, Nipreferi ma ngħidx*

6b) Jekk iva – Liem organizzazzjonijiet inti membru tagħhom? Jekk le tista tikteb N/A

6c) Jekk iva, x'inhu l-rwol f'din l-organizzazjoni?
Amministrazzjoni, Membru Attiv, Membru mma mhux daqshekk attiv/a, Senior member, Miniex membru, Oħrajn (jekk joġbok speċifika)

7) **Liem 3 kelmiet jiġuk f'moħħok meta tisma l-kelma 'xjenza'?**

8a) **Inti interessat fix-xjenza?**
Iva, Le, Ma nafx, Nippreferi ma ngħidx

8b) Jekk iva, liem aspetti tax-xjenza jinteressawk? Jekk le tista tikteb N/A

9) **Qatt ħdimt fil-qasam tax-xjenza?**
Iva, Bħalissa qed naħdem fil-qasam tax-xjenza, Iva, imma m'għadnix, Le, Ma naħdimx fil-qasam tax-xjenza, Le, qatt ma ħdimt fil-qasam tax-xjenza, Nippreferi ma ngħidx.

10) **Tattendi attivitajiet/avenimenti relatati max-xjenza?**
Iva, Le, Ma nafx

11a) **Kemm tiffrekwenta dawn ċ-ċentri, mużewijiet u festivals tax-xjenza?**
Esplora, Life science park, Malta national aquarium, National Museum of Natural History, Malta maritime museum, Science in the city, Science in the citadel.
Kull sena, Meta jkolli ħin, Darba, Qatt, Ma smajtx bih dan ċ-ċentru/festival, Nippreferi ma ngħidx.

11b) **Kemm il-darba attendejt avvinmenti organizzati min NGO's (organizzazjonijiet non-governmentali), din l-aħħar sena?**
Cinexjenza, Cafe Scientifique Gozo, Malta Cafe Scientifique, Kids Dig Science, Other (Please specify)
Kull sena, Meta jkolli ħin, Darba, Qatt, Ma smajtx bih dan ċ-ċentru/festival, Nippreferi ma ngħidx.

12a) **Jiena nipreferi nitgħallem fuq żviluppi u riċerka fix-xjenza min:**
Internet, Newspapers, TV, Radio, Podcasts, Blogs, Science events, *Oħrajn (jekk joġbok speċifika)*
Ma naqbel xejn, Ma naqbilx, Newtrali, Naqbel, Naqbel ħafna, Nipreferi ma ngħidx.

12b) **Jien nipreferi nitgħallem fuq żvliuppi u riċerka fix-xjenza mingħand:**
Gvern (e.g. Ministeru ta l-Edukazzjoni u x-Xogħol), l-Kunsill tax-xjenza u teknoloġija (MCST) (e.z. Esplora), Non-governmental organisations (e.z. Birdlife, Astronomical society of Malta etc), Media (e.g. PBS), l-Universita' ta' Malta, Malta College of Arts, Science and Technology (MCAST), l-industrija, *Oħrajn (jekk joġbok speċifika)*
Ma naqbel xejn, Ma naqbilx, Newtrali, Naqbel, Naqbel ħafna, Nipreferi ma ngħidx.

12c) **Kemm tħossok nfurmat fuq x-xjenza (teknoloġija) u innovazzjoni?**
Nfurmat ħafna, Nfurmat, Newtrali, Ftit li xejn infurmat/a, Mhux infurmat, Ma nafx.

Appendix 3

Information sheet, consent form, and members of PENs questionnaire

Headline/Title: Questionnaire to people involved in networks

List of networks: Criteria to choose networks
Diverse engagement of stakeholders with science
Diverse network members

Global networks with a focus on or at least sections for public engagement with science:

- PCST - (Public Communication of Science and Technology) https://www.pcst.co/
- WFSJ - (World Federation of Science Journalists) http://wfsj.org/v2/
- Living knowledge (The international science shop network) https://www.livingknowledge.org/
- INGSA - (International Network for Government Science Advice) https://www.ingsa.org/
- IECA - (The International Environmental Communication Association) - https://theieca.org/resources/organizations/science-communication-network-scn
- GLOBE - (Global Learning and Observations to Benefit the Environment) - https://www.globe.gov/

Trans-national networks

- Redpop - Latin American - https://www.redpop.org/

Europe-based networks

- EASST (European Association for the Study of Science and Technology) https://easst.net/
- ECSITE (European network of science centres and museums) https://www.ecsite.eu/
- EUSEA (European Science Engagement Association) https://eusea.info/
- Euroscience https://www.euroscience.org/
- EUPRIO (European Association of Communication professionals for higher education) (network of press officers) https://www.euprio.eu/
- EUCU (European Children's Universities Network) https://eucu.net/

National networks

- British Science Association - https://www.britishscienceassociation.org
- Bundesverband Hochschulkommunikation - https://www.bundesverband-hochschulkommunikation.de/home/
- AAAS - https://www.aaas.org Focus area- Public engagement
- AKSON https://akson.science/
- Australian Science communicators ASC https://www.asc.asn.au/join/
- Science Communicators Association of New Zealand (SCANZ) https://www.scanz.co.nz/

Questionnaire starts from here:

Consent form for Participating Adults

The following information will explain why you are being asked to take part in a survey and what happens to the information you provide. You will also be asked to provide your explicit consent for Danielle Martine Farrugia to make use of the data gathered from the interview for her Ph.D. entitled

RRING

"Towards a national strategy for Public Engagement with Science" at the University of Malta and the EU project RRING (rring.eu/)

How much time is needed to participate?

Once you give your consent, you will be asked to participate in a survey on public engagement with science networks. This survey should take about 25 minutes to complete. However, you may withdraw from participating in this research at any time and for any reason.

What happens to the information you provide?

Providing your consent to participate means that your responses will only be used for research and analysis purposes related to Danielle Martine Farrugia's doctoral studies at the University of Malta and the EU project RRING (rring.eu). The studies will provide a better understanding of the current trends in science and how citizens and other major stakeholders are engaging with science.

Research reports or publications will not include your name or any personal association with quotations or reported statistics. Furthermore, your personal information will be kept confidential, and we will not quote responses in marketing materials unless you provide explicit consent.

Agreement to Participate

Please read the following statements:

- My responses will be used for research and analysis purposes only. Also, my personal information will only be used for these purposes.
- When my responses are used for reporting or publication, my identifiable personal information will be removed from quotations or reported statistics.
- The information I provide about myself is confidential. My identity will not be disclosed to a third party or made public. This may require replacing my name with a pseudonym to protect my identity.
- My participation is voluntary, and I can withdraw at any time.
- I have received adequate information about my participation in this study and understand what will happen to the information I provide.

If you do not agree with any part of the consent requested below or would like clarification before starting, or have difficulties completing this form, please advise or send an email on
1.1. Please indicate whether you understand the information provided above and that you are willing to participate in this study:

☐ Yes, I understand and I'm willing to participate in this study
☐ Yes, I'm willing for my responses to be recorded (with no name attached)

I, the undersigned, have read the information presented in this sheet and agree to give my consent to participate in this interview.
Signed: ______________________________________
Dated: ______________

Page 1

Introduction:
This survey is about understanding the motivations and added value for people to join networks whose function is to engage various stakeholders with science. This project is part of Danielle Martine Farrugia's doctoral research and the RRING project. Professors Alexander Gerber & Prof. Paul Pace oversaw the development of the questionnaire. The questionnaire will take approximately 25 minutes to complete.

All questions are compulsory except for those marked with an *

General information

Age*(Restriction numbers) 3 characters*
Gender -
Options: Male/Female/Other
General area of employment (Dropdown list) - To choose 1

- Education (not university)
- Media / self-employed freelance journalist
- PR / marketing agency
- Research institution & Research at University
- Science centres & Museums
- Business/Industry
- Retired
- Other (please specify)__________

Years of work experience in the field mentioned above *(Numerical field) 3 characters*
Country of Residence *(20 characters)*
Nationality *(20 characters)*
Respondents will be directed to page 2 by clicking on 'Proceed to the next page'
Page 2

Membership/ Activity and commitment

1. Are you involved with any network/s related to or entirely focused on public engagement with science? Yes/No/Not sure/Prefer not to say *If yes:* Please specify *If no, proceed to question 10*

2. What networks are you a paying member of that are related or entirely focused on public engagement with science? (Matrix Style - can choose more than 1.
    - AAAS- American Association for the Advancement of Science Focus area- Public engagement
    - AKSON - Association of Communicators in Education and Science
    - Australian Science Communicators (ASC)
    - British Science Association (BSA)
    - Bundesverband Hochschulkommunikation
    - EASST - European association for the study of science and technology
    - ECSITE - European network of science centres and museums
    - Euroscience

- EUSEA - European Science Engagement Association
- GLOBE - Global Learning and Observations to Benefit the Environment
- IECA - The International Environmental Communication Association
- INGSA - International Network for Government Science Advice
- Living knowledge
- PCST - Public Communication of Science and Technology
- Science Communicators Association of New Zealand (SCANZ)
- Redpop - Network of popularization of Science and Technology in Latin America and the Caribbean (RedPOP)
- WFSJ - World Federation of Science Journalists
- Other (Please specify)

Please answer the following questions about the network that you identify with most strongly, that is related or entirely focused on public engagement with science. If you are a member of more than 1 network, you will be given the opportunity to fill in the following questions for another network.

Please specify the name of the network you identify with most strongly here (50 characters)
Once they fill in questions 3-9, the respondents will be given the option to fill in the questions for another network that they form part of. The network specified at the beginning will show throughout the questionnaire (to serve as a reminder).

3. How were you introduced to this network? You can choose more than 1 option.

Friends, Online, Heard about it at a conference, Email, Flyer, Work colleague, UnsureOther (Please specify)

4. What were your motivations to become a member of this network? - You can choose more than 1 option.

   To network, To learn about science communication, To increase knowledge on how to evaluate events, To learn about training opportunities, Unsure, Other (Please specify)

   Matrix Likert scale

5. **Please rate**:

a) I am **currently contributing** with the following aspects to the network I am a member of. Options: Extremely likely , Likely, Neutral, Unlikely, Extremely unlikely, Prefer not to say.
   - Time (organisation, administrative, etc)
   - Knowledge about communicating with various stakeholders
   - Contacts of various stakeholders
   - Financial
   - Mentoring
   - Writing proposals
   - Other (Please specify)

b) I **am able to contribute** with the following aspects to the network I am a member of. Options: Extremely likely , Likely, Neutral, Unlikely, Extremely unlikely, Prefer not to say.
   - Time (organisation, administrative, etc)
   - Knowledge about communicating with various stakeholders
   - Contacts of various stakeholders
   - Financial
   - Mentoring
   - Writing proposals
   - Other (Please specify)

Respondents will be directed to page 3 by clicking on 'Proceed to the next page'
Page 3

Questions about the model, structure, management of networks

Likert scale Matrix style block: Options: Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree, Do not know, Prefer not to say.

6. **Please rate:**

a. The network's vision is clear to me.
b. I find it difficult to relate to the network's mission. *Reverse coded*
c. The network's objectives are difficult to understand. *Reverse coded*
d. I fully support the goals of the network
e. The network's leadership is effective.
f. The network's leadership regularly evaluates the network's effectiveness.
g. The network hinders improvements in my public engagement with science work. *Reverse coded*

Communication and participation between the network and its members

Likert scale Matrix style block: Options: Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree, Do not know, Prefer not to say.

7. Please rate:

a. The network leadership is involved with a diverse range of stakeholders such as governments, media, citizens, civil society, industry, scientific community, etc
b. The network fails to provide the professional support I need. *Reverse coded*
c. The network makes me more effective in achieving public engagement-related objectives.
d. The network should provide greater support for skills development. *Reverse coded*
e. The network enables sharing best practices.
f. Conferences organised by the network are irrelevant to my work. *Reverse coded*

8. Which communication channel do you use most with other members within the specified network that you form part of? *Options:* E-mails, Meetings, Conferences, Social Media accounts, Messaging applications, Mailing lists(including e-mails) Other (Please specify)(, Prefer not to say

Knowledge about the network

9. a *Filter question* Does the network promote good ethical practices?e.g. privacy and data protection issues, involvement of vulnerable groups etc *Options:* Yes/No/Unsure/Prefer not to say *If yes, proceed to the next question, if not/unsure proceed to the next instructions'*
b. Which policies and regulations, if any, **encourage** good ethical practices in the network? (250 characters)
c. Which policies or regulations, if any, **hinder** good ethical practices in the network? (250 characters)
Respondents will be directed to page 4 by clicking on 'Proceed to the next page'
Page 4
Would you be willing to respond to the previous set of questions for another network? [Yes/No]
Maximum number of times 3 Once they fill in questions 3-9, the respondents will be given the option to

fill in the questions for another network that they form part of. The network specified at the beginning will show throughout the questionnaire (to serve as a reminder).

If Yes start from question 3, If no: Instructions to participant:

Please proceed to the questions below:

10. What would make you want to stay a member of a network for the long term? (tick all that apply)
    Effective leadership, Good management of funds, Transparency of decisions, Useful services, Prestige, Policy impact, Diverse membership, Other (please specify)
11. What keeps you from joining other public engagement with science networks? You can choose more than one option

Options: Lack of information about the network, Membership fees too high, Lack of relevance, Lack of useful benefits or services, Lack of prestige, I am too busy and do not have time to spare, Unsure, Other (Please Specify)

12. Have you ever left a professional network of any kind? *Options:* Yes/No/Prefer not to say *If no or Prefer not to say, Please proceed to the final message. If yes…*

12b. What were the reasons for leaving this network? You can choose more than one option

Options: Lack of time, Conflict between other members, Lack of leadership, Ineffective management, Lack of useful benefits or services, Lack of prestige, Vision of the network was not relevant to me anymore, Expensive membership fees, Other (Please specify)

Thank you for filling in this questionnaire. Should you have any questions about the questionnaire please contact

End of Survey

———————————————--

Appendix 4

Interview guide for Maltese entities

Consent form for Participating Adults

Evaluation Participation

The following information will help to inform you about why you are being asked to take part in an interview and what happens to the information you provide.

How much time is needed to participate?

Once you give your consent, you will be asked to participate in an interview about how science is communicated with different stakeholders/actors. This interview should take about **50 minutes** to complete. However, you may withdraw from participating in this research at any time and for any reason.

What happens to the information you provide?

Providing your consent to participate means that your responses will only be used for research and evaluation purposes, within Danielle Martine Farrugia's doctoral studies at the University of Malta. The studies will provide a better understanding of the current trends in science and how citizens and other major stakeholders are engaging with science.

Research reports or publications will not include your name or any personal association with quotations or reported statistics. Furthermore, your personal information will be kept confidential and your responses will not be quoted in marketing materials unless you provide explicit consent. The interview will be audio recorded and only kept for analysis. The audio recording's speed will be slowed down and the file will be saved under a pseudonym.

Agreement to Participate

Please read the following statements below:

- My responses will be used for research and evaluation purposes only. Also, my personal information will only be used for these purposes.
- When my responses are used for reporting or publication, my identifiable personal information will be removed from quotations or reported statistics.
- The information I provide about myself is confidential. My identity will not be disclosed to a third party or made public. This may require replacing my name with a pseudonym to protect my identity.
- My participation is voluntary, and I can withdraw at any time.
- I have received adequate information about my participation in this study and understand what will happen to the information I provide.

If you do not agree with any part of the consent requested below or would like clarification before starting, or have difficulties completing this form, please advise or send an email

1.1. Please indicate whether you understand the information provided above and that you are willing to participate in this study:

☐ Yes, I understand and I am willing to participate in this study.

1.2. Please indicate whether you are accepting to have your responses recorded. The recording will not be made public.

☐ Yes, I am willing for my responses to be recorded (with no name attached)

Your participation in this interview will inform Danielle Martine Farrugia regarding her PhD entitled ‘Towards a national strategy for Public Engagement with Science’ at the University of Malta.

I, the undersigned, have read the information presented in this sheet and agree to give my consent to participate in this interview.

Signed: ______________________________________

Dated: _____________

1) Keeping in mind how research and innovation policies/strategies are set in your institution, to which extent are these strategies **driven** by the aspects below? Can you **prioritise** the aspects in terms of your respective institution?

- STEM uptake & STEM careers (Probe STEAM)
- Economic needs
- Scientific excellence
- Responsible research and innovation
- Community participation in scientific research projects
- Media
- Other

2) Through what **channels of communication** is science communicated in your institution? *Probe: Channels of communication, Print media, Online media, Visual/audio, paper publications, UM channels (newspoint, THINK, campus FM). Why are these the most popular?* 3) What strategy has the [institution] developed to **actively engage** a variety of **stakeholders/actors** to participate in **national discourse** of science and technology to the benefit of civil society? 4) What are the [Institution's] **expectations** to communicate science to different stakeholders/actors? *5)* How does the [Institution] **educate** different stakeholders/actors about science, both formally and informally? *Probe: Is there a clear distinction between educating audiences and communicating the results and processes? 6) In your opinion, what are the scientific topics that the country needs to engage in based on Malta's needs? 7)* Mention some of the scientific topics that civil society at large is currently engaging in. Do these scientific topics align with the country's needs? *Probe: Environment/Health/Technology – blockchain etc*

8) Is there **training available for staff** on how to communicate scientific research to citizens who do not have a scientific background*? Probe: What skills are necessary to communicate scientific research? What kind of training is taking place and in what format? What does this training cover?*

9) Does government have a **stake** in determining how the communication of scientific research and innovation takes place? What do you think are the reasons for this?

10) Do different political parties in Malta have different policies? How does this **affect the process** of policy making as to how science is to be communicated between and to different stakeholders?

11) What is your vision as **[insert working position]** about the involvement of stakeholders in public engagement of science*?*

12) What is your **personal vision** about the involvement of stakeholders in public engagement of science?

Appendix 5

Information sheet, consent form and interview guide for senior members of international PENs

RRING

Consent form for Participating Adults

Evaluation Participation

The following information will help to inform you about why you are being asked to take part in an interview and what happens to the information you provide.

How much time is needed to participate?

Once you give your consent, you will be asked to participate in an interview about network structures and practices that are employed in public engagement with science networks. This interview should take about **60 minutes** to complete. However, you may withdraw from participating in this research at any time and for any reason.

What happens to the information you provide?

Providing your consent to participate means that your responses will only be used for research and evaluation purposes, within Danielle Martine Farrugia's doctoral studies at the University of Malta and the RRING project [http://www.rring.eu/]. The studies will provide a better understanding of the sustainability of public engagement with science networks

Research reports or publications will not include your name or any personal association with quotations or reported statistics. Furthermore, your personal information will be kept confidential and we will not quote responses in marketing materials unless you provide explicit consent. The audio of the interview will be recorded and only kept for analysis.

Agreement to Participate

Please read the following statements below:

- My responses will be used for research and evaluation purposes only. Also, my personal information will only be used for these purposes.
- When my responses are used for reporting or publication, my identifiable personal information will be removed from quotations or reported statistics.
  ● The information I provide about myself is confidential. My identity will not be disclosed to a third party or made public. This may require replacing my name with a pseudonym to protect my identity. ● My participation is voluntary, and I can withdraw at any time.
- I have received adequate information about my participation in this study and understand what will happen to the information I provide.

If you do not agree with any part of the consent requested below or would like clarification before starting, or have difficulties completing this form, please advise or send an email

1.1. Please indicate whether you understand the information provided above and that you are willing to participate in this study:

☐ Yes, I understand and I am willing to participate in this study.

1.2. Please indicate whether you are accepting to have your responses recorded. The recording will not be made public and will be destroyed once analysis has been conducted.

☐ Yes, I am willing for my responses to be recorded (with no name attached)

1.3. Please indicate whether you are also for your submitted responses to be anonymously used in marketing materials:

☐ Yes, I am willing for my responses to be used in marketing materials (with no name attached)

Your participation in this interview will inform Danielle Martine Farrugia regarding her PhD entitled 'Towards a national strategy for Public Engagement with Science' at the University of Malta and the RRING project [http://www.rring.eu/].

I, the undersigned, have read the information presented in this sheet and agree to give my consent to participate in this interview.

Signed: ______________________________________

Dated: ______________

General information (Demographic Data)

Gender____________ Female/Male/Other

Age___ (Numerical)

General Area of Employment

	Interview Questions to Ask
1	a. What network do you form part of? b. What is your current role within the network? c. How long have you held this role within this network?
2	Does your work involve individuals or organisations from outside of your team and your work on public engagement with science within this network? *[NOTE: This is a 'Yes / No' filter question, which funnels participant questions down a) or b) paths below]* **[If No]** a) Have you worked with other networks, where your work involved individuals, organisations or other networks? Please specify **ii)** Would you prefer to involve outside individuals or organisations, and if so why? If not, why not?
	[If Yes] i. What types of individuals, organisations or networks, have you involved in your work? ii. How do you include people or organisations, networks from outside of your group in your work? (What role do they have?) iii. In your view, what have been good ways of involving external individuals, organisations and networks in planning or decision-making in your field? iv. When do you think it is inappropriate to involve external individuals and organisations in your work? v. In your professional experience, what government policies and regulations encourage or hinder the process of involving individuals not part of the network and other networks? vi. What institutional policies or regulations within your current or former organisation encourage or hinder the process of involving individuals not part of the network and other networks? vii. What norms and practices in your field encourage or hinder the process of involving individuals not part of the network and other networks?
3a	What ethical issues, if any, are relevant to your work within the network?
3b	[i]How important is it for your work to consider societal needs? (Why?) [ii]How do you assess the implications of your work as you develop and implement your plans for the role in the network you form part of?
Management & Governance of network	

4.	How would you describe the Governance operations of the network?
5.	Is the current governance structure a good fit for the network? *Yes/No question* (i) If yes, what makes it so? (ii) If no, what would you change within the government structure?
6.	Are you aware of the variety of roles within networks? *This is a YES/NO filter question* If **[Yes]:** What roles are there within the network that you form part of that focus on public engagement with science? How do they sustain the network? If **[No]**: What roles do you think are significant for a well managed networks with a focus on public engagement with science?
7.	How effective do you think the leadership style of the network is? (i)Do you know how the governance of your network documents its meetings? Are they publicly available? (ii)What topics are mostly discussed in your network?
8.	How does governance operate the network? What topics are mostly discussed in your network? Follow up - Are these topics discussed at governance level?
Funding and Funding models within the PEN	
9.	(i) Where do networks in general acquire its funds from? (ii) Where does the network you are part of acquire its funds from?
10.	Do you know how the funds are distributed and how who takes the decisions, within your network that focuses on public engagement with science? *YES/NO question followed by:* **If [Yes]:** How are the funds distributed within the public engagement with science network that you form part of? How does the network make sure that there is no negative balance at the end of the year? **If [No]:** How do you think that funds are to be distributed within the public engagement with science network that you form part of?
Membership	
11.	In your opinion, what is the ideal number of members for a network that focuses on public engagement with science? Does the amount of members within a network have an impact on the overall effectiveness in the management of the public engagement with science network?

12a.	[i] How does the network attract new members? Has it proven to be successful? [ii] How does the network stay relevant for its members?
12b	[i] How does the network keep track of membership fees? [ii] How are the membership fees distributed within the network?
14c	Do network members exercise their rights to involve themselves within the public engagement with science network?What rights do network members have, e.g. voting, is there a hierarchy and how is this conceived e.g. different categories of monetary contributions. Please specify the network
13.	Would you say that the structure of the network that you form part of supports good relationships between network members? *Yes/no question* If **[yes]**: How does the structure of the network help to ensure good relationships between network members? If **[no]:** What is lacking in the structure of the network to ensure good relationships between network members?
14.	[i]What are the most common communication channels the network uses to communicate with its members? How does the network communicate with its members? [ii] Do you think these methods have been effective in sustaining the network?
Network Creation and Evolution	
15.	To your knowledge, what were the motivations behind creating the network?
16.	Was there any need for the structure of how the network is governed to change throughout its years of existence? Has the structure of how the network is governed changed throughout its existence? Follow up - Were there any instances that prompted the change in the structure of the network that you form part of?
17.	[i]Has the way the network communicates with its network members changed over the years? Yes/No [ii] If so how has this changed over the years? In your opinion, has this enhanced or diminished the level of participation of network members within the network that you form part of?
18.	To your knowledge, could you describe the values that motivate the network you form part of?
19.	How would you define success in a network?
Inclusivity	

20.	How does the network involve people with different backgrounds, who may bring new perspectives, concerns and needs to your attention?
21.	(i)There is a lot of discussion about the idea that women need to be equally represented in research and innovation. How do you feel about this topic and its relevance to the network that you are part of? (ii)What other underrepresented groups is the network reaching out to, if at all?
b	*Follow up questions if participant gives a positive response about relevance of diversity:* ● What are the most important institutional policies and regulations that either encourage or hinder equal participation of diverse groups in your field? ● What norms or standard practices in your field either encourage or hinder equal participation of diverse groups in the network that you are a member of?
c	*If the participant gives a negative response about relevance of diversity, ask the respective question below:* What are the main reasons for you to not consider that equal participation of people of diverse backgrounds is not a relevant issue within the network?
22.	Before we finish, is there anything else you would like to add relating to what we have discussed?

Appendix 6

Sampling Distribution of two population proportions

Sampling Distribution of two population proportions

Let n_1 be the total number of participants in the sample and let X_1 be the number of females in this sample. Similarly, let n_2 be the population size and let X_2 be the number of females in this population. The sample proportions $\bar{p}_1$ and $\bar{p}_2$ are:

$$\bar{p}_1 = \frac{X_1}{n_1} \text{ and } \bar{p}_2 = \frac{X_2}{n_2}$$

The central limit theorem states that the random variable z (z-score) has an approximate standard normal distribution where

$$z = \frac{(\bar{p}_1 - \bar{p}_2) - (p_1 - p_2)}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}} \text{ where } \hat{p} = \frac{X_1 + X_2}{n_1 + n_2}$$

where p_1 and p_2 are unknown proportions. In order to test whether there exist a significant difference between the two unknown proportions p_1 and p_2, we specify the following hypotheses:

$H_0 : p_1 - p_2 = 0$
$H_1 : p_1 - p_2 \neq 0$

If we test for H_0, the variable z becomes $z = \frac{(\bar{p}_1 - \bar{p}_2)}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}}$ since $p_1 - p_2 = 0$.

The p-value is the area under the standard Normal distribution beyond the values of $\pm z$ calculated using the above formula.

If the p-value exceeds the 0.05 level of significance H_0 is accepted implying that the two unknown proportions p_1 and p_2 are comparable. If the p-value is less than the 0.05 level of significance H_1 is accepted implying that the two unknown proportions p_1 and p_2 differ significantly.

Example

Out of 573 participants in the sample, 294 were females. Moreover, out of 432616 individuals living in Malta, 209259 are females

So $n_1 = 573$, $X_1 = 294$, $n_2 = 432616$ and $X_2 = 209259$

$$\bar{p}_1 = X_1 / n_1 = \frac{294}{573} = 0.5131 \text{ and } \bar{p}_2 = \frac{X_2}{n_2} = \frac{209259}{432616} = 0.4837$$

$$\hat{p} = \frac{X_1 + X_2}{n_1 + n_2} = \frac{294 + 223357}{432616} = \frac{223651}{432616} = 0.5170$$

$$z = \frac{\bar{p}_1 - \bar{p}_2}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} = \frac{0.5131 - 0.4837}{\sqrt{(0.4837)(0.5163)\left(\frac{1}{573} + \frac{1}{432616}\right)}} = \frac{0.0210}{0.0208} = 1.407$$

For $z = \pm 1.407$, the p-value is 2(0.158) = 0.316, which exceeds the 0.05 level of significance. So H_0 is accepted. Hence we can deduce that the difference between the two proportions is not significant.