Hidden Engagements: Exploring Europeans' Public (Dis)Engagement with Science

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Acknowledgements

Random family member: So, you say you are doing research.
Me: Yes!
Random family member: So, what exactly are you looking for?
...
(The answer to this question has been bugging me for the past 3 years)

Apparently, this is the last stage of education. *Finally!*, any *random family member* of mine would say in a relieved but confused tone. *Already?!*, I would say in a not-so-relieved and even more confused tone. Education has occupied most of my existence, and the vast majority of my thoughts and future self-projections. It has not always been smooth, but it has definitely been a very privileged path for which I am extremely grateful. Clearly, not all of it relied on my effort only, and especially in this last step there are many people who I wish to acknowledge. In the following few paragraphs, I highlight the fundamental contributions of people and institutions who collaborated to make the past three years possible, enriching, and enjoyable.

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To all of you, Grazie.

Preface

Voglio essere libero, libero come un uomo	I want to be free, free like a man
Come un uomo appena nato	Like a man just born
Che ha di fronte solamente la natura	Who faces only nature
Che cammina dentro un bosco	Who walks within a forest
Con la gioia di inseguire un'avventura	With the joy of chasing an adventure
Sempre libero e vitale	Always free and vital
Fa l'amore come fosse un animale	Makes love as if he were an animal
Incosciente come un uomo	Unconscious like a man
Compiaciuto della propria libertà	Pleased with his own freedom
La libertà non è star sopra un albero	Freedom isn't sitting atop a tree
Non è neanche il volo di un moscone	Nor even the flight of a fly
La libertà non è uno spazio libero	Freedom isn't an open space
Libertà è partecipazione	Freedom is participation
Vorrei essere libero come un uomo	I would like to be free like a man
Come un uomo che ha bisogno di spaziare con la propria fantasia	Like a man who needs to roam with his imagination
E che trova questo spazio	And finds this space
Solamente nella sua democrazia	Only in his democracy
Che ha il diritto di votare	Who has the right to vote
E che passa la sua vita a delegare	And spends his life delegating
E nel farsi comandare	And in being commanded
Ha trovato la sua nuova libertà	Has found his new freedom
La libertà non è star sopra un albero	Freedom isn't sitting atop a tree
Non è neanche avere un'opinione	Nor even having an opinion
La libertà non è uno spazio libero	Freedom isn’t an open space
Libertà è partecipazione	Freedom is participation
Vorrei essere libero come un uomo	I would like to be free like a man
Come l'uomo più evoluto	Like the most evolved man
Che si innalza con la propria intelligenza	Who rises with his intelligence
E che sfida la natura	And challenges nature
Con la forza incontrastata della scienza	With the unquestionable force of science
Con addosso l'entusiasmo	With enthusiasm

Di spaziare senza limiti nel cosmo	To roam limitless in the cosmos
È convinto che la forza del pensiero	And convinced that the power of thought
Sia la sola libertà	Is the only freedom
La libertà non è star sopra un albero	Freedom isn't sitting atop a tree
Non è neanche un gesto o un'invenzione	Nor even a gesture or an invention
La libertà non è uno spazio libero	Freedom isn't an open space
Libertà è partecipazione	Freedom is participation
La libertà non è star sopra un albero	Freedom isn't sitting atop a tree
Non è neanche il volo di un moscone	Nor even the flight of a fly
La libertà non è uno spazio libero	Freedom isn't an open space
Libertà è partecipazione	Freedom is participation

Giorgio Gaber was an Italian singer-actor, a Milanese singer-actor to be precise. Together with his co-writer Sandro Luporini, he pioneered a novel genre in Italy the 60s known as song-theatre (*teatro canzone*) which precludes the narration of stories themed around the human experience to be sang on stage followed accompanied by music played by an orchestra. The excerpt above is part of a song included in the show titled "*Dialogue between an engaged man and an I-don't-know*" (*Dialogo tra un impegnato e un non so*, 1972-3). The elements of the show vary from ironic poems about shampoo to angry ballads about social inequality. Overall, the show puts together reflections over topics from everyday life and social organization markedly inspired by the then-recent social uprising and political contestation. In the song above, titled "*Freedom*" (*La Libertá),* Gaber and Luporini describe various interpretations and ideas of freedom, repeating their own interpretation of freedom in the refrain. According to the authors, freedom is a collective term that can be found in being active members of society and in the exchange with others. Freedom seems to equal participation. Later on, the authors started questioning the core statement of the song, arguing that they themselves were actually not sure about the real meaning and implications of the word *participation*. How much participation is enough to grant freedom? What does participating mean?

Chapter 1
Introduction

About five years ago, outside of the door of one of the doctors working at the National Oncologic Institute in Milan was a sign that said *"Those who have already self-diagnosed through Google, but would like a second opinion, please check Yahoo.com"*[1]. The sign is just a humorous example from one person, but it can be used to illustrate interesting elements of the current relationship between science and society. It suggests that members of the public look for scientific information, medical in this case, in alterative settings, but they still resort to personal interactions, with experts, to validate their newly acquired knowledge. It also highlights the use of the online environment as the source of such (para)scientific information and it illustrates the integration of science and technology in everyday life as tools for problem solving. At the same time, it can be seen as exemplifying the resistance among experts to engaging with this newly (semi)empowered population whose knowledge is at times questionable but also in fact challenges the special, undisputed status of scientific authorities.

This anecdotal observation mirrors several of the elements around which academic research on the public understanding of science has been orbiting over the past decades. In particular, the constant tension between engaging *lay people* with science to enhance trust, and the opposite implications this can have for the role of science professionals as cultural authorities (Gregory & Lock, 2008). While on one side, the public has been invited to participate in science development and governance, on the other, applications of science communication following the *deficit model* (Irwin & Wynne, 1996), that is the idea that the public has a deficit of science knowledge that needs to be filled through outreach, have been unprepared to deal with the newly acquired ability of the public to *speak back* to science (Gibbons, 1999). This *speaking back* has often taken the shape of critiques to scientific authority, which in their shape and extent have been observed to vary across social groups, for example in terms of their level of education (Makarovs & Achterberg, 2017). Different social groups have different levels and modalities of access and interaction with scientific knowledge and these differences interact in various ways with

[1] Retrievable on the online version of the Italian newspaper *Corriere della Sera*. Last accessed on November 30th: https://www.corriere.it/salute/17_novembre_29/dottor-google-istituto-tumori-milano-66f4a960-d4e1-11e7-b070-a687676d1181.shtml

the internet and social media (Cacciatore et al., 2014; Gerosa et al., 2021). Digital media has made it easier for the public to access and retrieve science information unsupervised, although digital behavior is markedly different across social strata (Van Deursen & Van Dijk, 2014). These elements describe a picture of the relationship between science, society and individuals that can be accessed from various angles.

The proliferation of online science communicators across various social media platforms, fostering interactive engagement, coupled with scientists' *perceived* crisis of trust in science (Leshner, 2021), suggested a disjunction between the popularization of science and its rejection or questioning. Puzzled by this, my initial research focus was on the cultural authority of science and its negotiations in the online environment. However, as my time as a PhD student progressed, one of the elements of this relationship acquired prominence: the active involvement of the public with science. This dimension appeared to precede these discourses temporally and logically, although it was underdeveloped in some respects. While research on the science–society relationship in terms of Public Understanding of Science (PUS) is extensive concerning the perspectives of lay individuals towards science (e.g. Gauchat, 2011) and how context and individual characteristics affect science attitudes (e.g. Makarovs & Achterberg, 2017), the same cannot be said for research on public engagement with science. On this topic, the literature mainly includes theoretical elaborations on the importance of engagement for science (Weingart et al., 2021) and assessment of the products of engagement initiatives and processes (e.g. Jensen & Buckley, 2012; Davies et al., 2019). However, the interconnections among these elements, that is the differences in engagement among different types of individuals and how it can vary across groups, have been introduced (Makarovs & Achterberg, 2018) but remain largely unexplored. This is particularly the case concerning our understanding of groups that are typically considered as "disengaged" with science and how their relation to science can be characterized. In this dissertation, I aim to bridge this gap in knowledge. Exploring the concept and the implications of public engagement with science entails navigating a complex terrain involving a variety of other interacting elements in relation not only to science but also to broader themes as society, politics, individual and social disparities. The multifaceted nature of public engagement with science allows my diverse interests to converge in producing an informative, comprehensive, and hopefully coherent exploration of the relationship between science and the public.

Up to this point, I have elaborated on the rationales behind my choice of building a dissertation focusing on public engagement with science. In the next section, I provide a brief contextualization of this concept within the research field of public understanding of science, illuminating its origins and trajectories. Subsequently, I describe the relevance of this concept in both the research and policy domains. I introduce the core debates in the academic literature of public engagement with science and locate my main research question. I end this chapter with an overview of the contents of this dissertation.

1.1 The origin of Public Engagement with Science

Public Understanding of Science: literacy and education

The origin of the concept of Public Engagement with Science is related to the birth of the overarching field of Public Understanding of Science (PUS). This and the related research on the relationship between science and the public is associated with a report commissioned to a group of researchers chaired by Walter Bodmer and published by the British Royal Society in 1985. This document, colloquially known as Bodmer Report, is a collection of recommendations on how to enhance the public's knowledge of science, suggesting initiatives for school, the media, government, and scientists themselves. The underlying assumption that motivated the report and guides its suggestions is that the public's disinterest and negative attitudes towards science weaken science's social authority and this should be addressed by promoting science knowledge (Gregory & Lock, 2008). Indeed, the assumption underlying the report was that increased factual knowledge and understanding of the science processes would necessarily produce more positive attitudes towards it among members of the population (Gregory & Miller, 1998; Bauer, 2009). This way of interpreting the relationship between science and the public is influenced by decades of increasing debates on the role of science in society, and the importance of public recognition and appreciation of science that succeeded the developments from the second world war (Gregory & Miller, 1998).

The creation of the Bodmer Report also followed two decades of political protests of the 60s and 70s, and together with most of the studies that came after it, tried to address the perceived crisis in the trust relationship between science and members of the public (Gregory & Lock, 2008). The solution proposed at the time was to educate the public and enhance their *science literacy*, but this solution soon seemed to fall short. Indeed, it has been observed that the critical debate around science could co-exist with both science knowledge and ignorance (Lewenstein, 2003; Gregory & Lock, 2008). The danger of society's lack of trust in scientists and the urgency to find instruments to resolve it were systematically formulated in the 1990s by Beck (1992), among others, in his seminal book *Risk Society*. His thesis was that members of the public started to believe that science could not fully protect them from the increasingly man-made risks that societies were facing, and indeed that these risks were more often provoked by science than solved by it. To better address this public concern, the idea of public dialogue with science started to gain attention as a possible addition to public education.

Callon (1999) presents these two approaches as distinct models of expert-public interaction, one focused on giving the public instruments to better understand science and the other on providing spaces for them to voice their concerns. Indeed, the approach developed in the 1990s has been observed to mark a separation from the research on the *Public Understanding of Science* (PUS) towards the *Science-in-Society* framework, in which the deficit investigated is no longer among the public but among the scientists who misinterpreted the population (Bauer, 2009). However, both these models share the same underlying motivation: restoring public trust in science and targeting public attitudes as the intervention site. Thus, following Cerroni and Simonella (2014:141), public dialogue can be understood as merely a refined instrument of public education. Nevertheless, this next phase in the development of academic literature of public understanding of science marks the introduction of ideas of inclusion and representation of the public in science, which will later widely inform the development of the model of public engagement with science.

Science in Society: dialogue, context and lay expertise

Following the distinction made by Lewenstein (2003), it is possible to distinguish a couple of approaches among the studies developed under the framework of public dialogue with science, although the boundaries are once again blurry: the *contextual* model and the *lay expertise* model. The *contextual* model emphasizes the importance of considering how members of the audience process information actively according to their social and psychological context. This is where explanations driven by the application of *rational choice* (see Raub, 2021 for an overview within the social sciences) start to be employed and developed to understand lay people's relationship with science (Bromme & Gierth, 2021 for a recent overview). This assumption of rational choice suggested that improving relations with society was mainly a question of finding better ways of delivering scientific knowledge that could deal with that complexity. Indeed, applications of the contextual model have been criticized for keeping the focus on the individual and psychological responses to science, while acknowledging the complexity of social settings, thus aiming at consensus rather than understanding (Lewenstein, 2003). The *lay expertise* model represents one step ahead. Indeed, Lewenstein (2003) explains that this model equates scientific knowledge with the knowledge of lay people facing certain scientific or technological issues, which should be acknowledged and valued in its own right. Lewenstein (2003) highlights that the core of this model is the view that to make impactful personal or policy decisions, scientists need to abandon their unreasonable certainty in scientific knowledge and recognize the contribution of local knowledge, based on the lives and histories of real communities. The implications of the implementation of lay expertise in science and technology decision-making is discussed in chapter 2. Here, I describe the importance of this model for the development and introduction of public engagement with science.

This way of interpreting the relation between science and the public is in sharp contrast with the theoretical and methodological standpoints that dominated the field until this point. Indeed, while surveys and quantitative analysis dominated precedent empirical analyses, in this new framework methodologies from the humanities and social sciences, such as constructivism, interview and case studies or ethnographies, start to be incorporated (Gregory & Lock, 2008). A notable example of this new wave of studies and their powerful contribution in reshaping the understanding of the public's role in science decision-making is Wynne's (1996) case study of Cumbrian sheep farmers. This study is set during the aftermath of the Chernobyl nuclear disaster in 1986 whose consequences affected various parts of Europe, including the Cumbrian countryside. Here the government, after an initial reassurance that there would be no harmful consequences for the population and agriculture, suddenly banned all sheep sales and movements in the affected areas. The study examines the farmers' reactions to these restrictions, which were strictly based on scientific advice. Indeed, the farmers were not only resentful because of the economic damage that the ban would cause them, but especially because their profound knowledge of that environment was systematically ignored. The decision-making process overlooked the valuable local knowledge of the farmers, leading to significant misjudgments of the situation and the breach of trust between farmers and scientific experts. In discussing the case, Wynne (1996) identifies the "own lack of reflexivity" (p.38) and lack of self-criticism among the science representatives as leading contributors to this situation. The importance of this study lies in the clarity with which it underlines the practical negative consequences that disregarding local knowledge has on policymaking and science-public relations. It highlights the need for scientific and governmental institutions to actively pursue an open dialogue with the public, extending this inclusivity to all social groups, such as the sheep farmers in this case. This approach soon after led to the final step in the acknowledgement of the importance of the public for science, and thus to the proposition of the public participation (Lewenstein, 2003) or co-production of knowledge (Callon, 1999) model, ultimately Public Engagement with Science (PES).

Public Engagement with Science: a shared development

The definition and motives of PES will be discussed in depth in chapter 2. I will introduce here its distinctive features that differentiate it from previous models of the relationship between science and society. Wynne's (1996) pivotal study paved the way for recognizing the importance of granting the public the possibility to engage with scientific institutions, despite their level of scientific literacy, and having their views seriously considered. This framework was novel in its aim not to privilege any voice in particular, but rather to create a shared understanding of science developments directions, responsive to needs and values of different social actors. However, while groundbreaking, the framework was also perceived as controversial, as reducing the traditional distance between science professionals and lay people might challenge the scientists' expertise and their authority (Gregory & Lock, 2008).

Thus, PES was developed, not to address technical science developments, but rather for addressing contemporary social issues regarding science and technology (Wynne, 2007; Gregory & Lock, 2008). Despite the noble and ambitious ideals that guided its formulation and adoption, PES has been criticized from various angles. It has, e.g., been criticized for targeting politics rather than science understanding, for serving a small part of the public, and for having an anti-science bias (Brossard & Lewenstein, 2009). At the same time, its applications have also been criticized for their novel *deficitarian* definition of public, meaning that individuals are understood to be without opinions and in need of engagement exercises to formulate them, and for substituting spontaneous popular democratic expressions with manageable structured activities (Gregory & Lock, 2008).

I conclude this section on the origins of the concept of public engagement with science with a note for interpretation. The order in which these models have been described might inadvertently imply a hierarchy of relevance. While they have historically succeeded each other, I sustain that this does not imply substitution. Each approach represents a useful analytical tool to understand and study the intricate relationship between science and society, as well as to elaborate policy instruments aimed at targeting it. This study contributes to the debate with the exploration of the concept of public engagement with science from the point of view of the public.

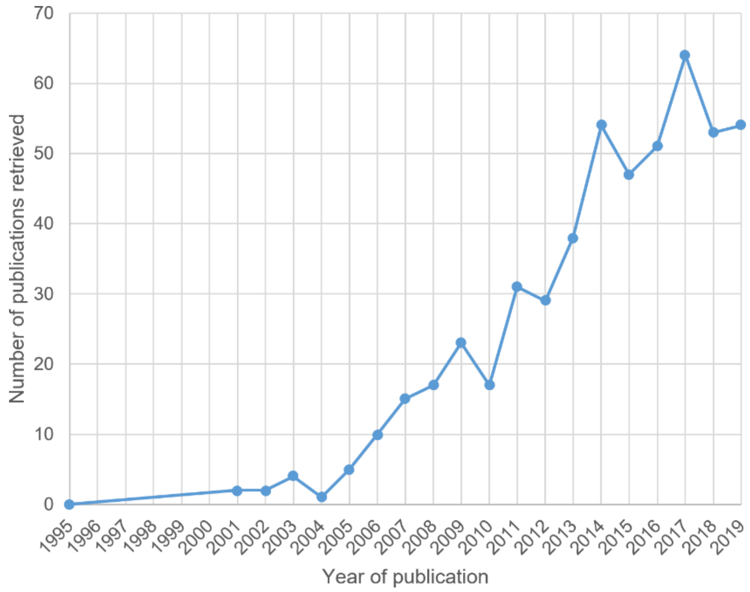
1.2 Contemporary relevance of Public Engagement with Science

Despite these critiques, Public Engagement with Science (PES), in its various definitions and applications, has gained prominence and has seen a sharp expansion in academic research and policy documents. This rise in academic interest towards PES has regarded both theoretical reflections on its value and implications (e.g. Bucchi & Neresini, 2007) and formulations of practical applications, such as citizen science (Irwin, 1995; Bonney, 1996;). Figure 1 is included in a recent review of the literature on PES (Weingart et al., 2021) and reports the growth in the occurrence of the combination of the terms "public engagement" and "science" in titles or abstracts in the Web of Science from 1995 to 2017 (n=517). The same review reports that engagement with science is a term increasingly found in policy documents as well. Beyond observing the trends over time in academic literature and policy materials, the authors provide an overview of the key motives attributed to PES and find that involving the public in science and technology related activities is driven by five main motivations:

- *Democratization.* Empowering citizens to actively participate in society and creating inclusive science-related practices contributes to the democratization of both science and society.
- *Education.* Engagement is seen as a vehicle to enhance public access to scientific knowledge and improve their science education.
- *Legitimation.* Promoting trust and acceptance of science and technology and science policy.
- *Innovation.* Engaging local expertise and informal knowledge is considered fruitful for science development and increased science social responsibility within scientific innovations.
- *Inspiration.* Raising interest in science and promoting science and technology related careers and labor force.

These motivations for public engagement with science are also promoted in policy documents, though with the notable exception of legitimation. Policy documents never explicitly mention the need to increase public acceptance of science, and more often emphasize the public gains of direct communication between science and the public (Weingart et al., 2021). Given this emphasis in policy documents on public engagement with science and the extensive academic focus on this topic, the present dissertation contributes to the growing body of knowledge with empirical evidence on lay people's experiences and practices of engagement with science, while questioning aims, definitions, and borders of engagement itself.

Figure 1. Trend of the mentions of “public engagement” and “science” in titles and abstracts of scientific articles from Weingart et al., 2021.



Note. Original figure DOI: https://doi.org/10.1371/journal.pone.0254201.g001

Despite the increasing interest in public engagement with science and the ambitious motives mentioned in academic and policy documents, its practice is faced with some challenges. In the following paragraphs I will articulate two main limitations to the practice of public engagement. One regarding the consensus-oriented approach often implicit in engagement initiatives and one regarding the lack of socio-demographic diversity of the (dis)engaged public.

A decade ago, Stilgoe and colleagues (2014) asked the question, *why should we promote public engagement with science?*, echoing an influential article from 1987 proposing a similar question about public *understanding* of science (Thomas & Durant, 1987). In their essay, the authors refer to a precedent publication by Stirling (2008) in identifying the importance of engagement with science through its potential impact on governance, but also in delineating the constraints often posed by its practical applications. As described by Gibbons (1999), the disruptive element of the modern structure of science is the moving of the arenas of negotiation from the traditional institutional locations to the public space, where society can “speak back” to science and demand societally legitimate and robust knowledge production. However, Stilgoe and colleagues (2014), as others before (e.g. Lidskog, 2008; Stirling, 2008), highlight how the emphasis on consensus formation that has guided most engagement initiatives hinders the emergence of discordant views, preventing engagement exercises from challenging and transforming existing policies. If normative assumptions guide the application of participatory exercises, these can hardly lead to new outcomes and will almost certainly confirm and reproduce the point of view inherent in the power structures that enabled them (Stirling, 2008). In alignment with what argued by Wynne (1996) a decade earlier, to tackle these shortcomings the authors propose a reflexive change of perspective in the academic approach to public engagement with science, which should abandon prerogatives of consensus formation towards a more explorative view of the engagement settings, modalities and outcomes. This recommendation is rooted in the recognition that scientists' perception of the public is a critical aspect for achieving meaningful engagement. Indeed, Stilgoe and colleagues (2014) argue that portraying the public as either devoid of own opinions or inherently holding hostile and anti-science attitudes is counterproductive, hindering open exchanges between the actors. Definitions and realities of the (dis)engaged public represent an open discussion in research on engagement with science, which links to the second challenging element of the engagement practice.

Another challenge facing the practical applications of PES regards ensuring the inclusivity and representativeness of the engaged public. In a recent contribution, focusing on one aspect of engagement with science, namely citizen science, Lewenstein (2022) highlights many problematic aspects regarding (in)equality that have permeated initiatives of public engagement with science in the last decades. The lack of diversity of the engaged public has been observed on various occasions and through various forms of science-related initiatives (Jensen et al., 2021; Paleco et al., 2021; Pateman et al., 2021; Jönsson et al., 2023). These studies show that generally science related activities are more popular among members of the public identifying as males, belonging to ethic majorities and with higher levels of education. Given the emphasis on the link between exercises of engagement with science and science governance or policy making, these disparities are problematic in terms of representation. Indeed, if only the privileged strata of society engage with science, the original goals of enhanced democratization, legitimation and innovation are challenged. However, science initiatives are not unique in this concern, as lack of equal representation is common among various realizations of governance and decision making. Issues of social inequality in political participation are a known and recurring topic in political science research (e.g. Jackson, 1995; Armingeon & Schädel, 2015). This dissertation, especially article B, draws on insights from literature of political behavior and political theory to operationalize the motivations behind scarce engagement with science among disadvantaged social groups. Despite the large number of studies observing socio-demographic, economic, and cultural disparities in engagement with science, research on the origins of these disparities and their implications for the disengaged population is still scarce (insights mostly from e.g. Archer et al., 2015, Dawson, 2019 and related publications). Given this framework, my main research interest for this study reads as following:

How do socio-demographic characteristics interact with public engagement with science?

Through this question, I focus on the *public* in public engagement with science and aim to understand the meaning that belonging to a particular socio-demographic, economic or cultural strata of society implies for engagement with science. By exploring this question, I do not intend to reiterate a conception of the public as *deficient* with respect to science. Instead, I aim at observing the mechanisms that lead certain parts of the public to be considered excluded from science, looking for evidence of these mechanisms both in the public and in scientific institutions. This question guides the development of the research project as a whole and has been operationalized in three sub-questions. These sub-questions are formulated in the final section of chapter 2, after the introduction of the main concepts guiding this dissertation.

1.3 Roadmap of the dissertation

This dissertation represents the conclusion of my time as a PhD student at the Danish Centre for Studies on Research and Research Policy at the Department of Political Science of Aarhus University. Through these three years, I have worked to understand the *public* in public engagement with science, and I have done so initially through existing survey data and subsequently through self-collected interviews with members of the public. By employing a variety of data sources and approaches I aimed at building a comprehensive and multifaceted understanding of Europeans' public engagement with science. In this summary, I provide a common framework to understand the three studies, which inform this project and discuss the general implications that can be derived from them while suggesting future research avenues.

In this first chapter I have introduced the research focus of this dissertation, Public Engagement with Science, and I have framed it within the development of the wider research field of Public Understanding of Science. Finally, I have placed this construct among the main academic debates concerning its aspirations and constraints. The practice of public engagement with science suffers from the temptation to generate consensus instead of innovative perspectives on science, which coupled with the narrow socio-demographic diversity of its public, endangers its ambitious democratization goals. This study contributes to widening our understanding of the workings of engagement with science and its interactions with individual socio-demographic characteristics.

In chapter 2, I build a conceptual framework around the elements that this dissertation is aiming to connect: characteristics of modern societies, the structure of science, and rights and duties of individual citizens. I introduce the corresponding elements that contribute to locating public engagement with science at the crossroad of these three elements, while showing the main theoretical concepts that guide the remainder of this dissertation. I characterize the societal context in which public engagement with science takes place through the concepts of Knowledge and Digital Society. After this setting, I discuss Mode 2 of Knowledge Production and (Lay) Expertise as defining features of the new structure of science. Finally, I describe the role of individuals in this context by means of Scientific Citizenship and Social Inequalities. I conclude the chapter by outlining the main elements characterizing public engagement with science: definitions, objectives, and reasons for (dis)engagement. At the end of this chapter, I include the three research sub-questions that guide the empirical studies.

In chapter 3, I discuss the methodological approach that I have applied to the overall project and the specific choices of methods and analysis for each sub-study. After an overview of the general research approach, I start by introducing the quantitative studies. I describe the secondary survey data that I have employed in article A and B, its advantages, and limitations, and motivate the design choices made. After this, I introduce the qualitative part of the project. I discuss the value of combining elements from opposite research traditions and highlight how each study carries an independent and collective contribution to the understanding of engagement. I then describe my approach to qualitative interviewing, the design choices, and their implications for the study. I end with explaining the challenges faced during the qualitative study and possible ways to address them.

The following three chapters, 4 to 6, include the empirical studies in the form of scientific articles. Table 1 includes an overview of the three articles that constitute the empirical material for this project. Article A is an exploratory quantitative study in which I employ Principal Component Analysis and Cluster Analysis on data from the Eurobarometer 516 to construct a typology of forms of engagement. In article B, I employ the same data to test hypotheses on the mediating role of science attitudes, in particular technocratic tolerance, in the relationship between socio-economic status and engagement with science. This study has been pre-registered online on the Open Science Framework platform and the link to the pre-registration is included in Table 1. Article C is a qualitative study in which I investigate the ways in which members of the public experience and perceive engagement with science. This study is based on self-collected interviews in which it was left to the informants to define engagement and science according to their own understanding, and it was approved by the Institutional Review Board of Aarhus University prior to data collection.

Table 1. Overview of the empirical studies included in this dissertation. All single authored

Article	Title	Publication information	Other information
A	Who engages with science and how? An empirical typology of Europeans' science engagement.	Published in August 2023 in *Public Understanding of Science* 32(6), 798-814.	-
B	Socio-Economic Status and Technocratic Tolerance. Understanding science (dis)engagement in Europe.	Under review in *Public Understanding of Science*. Received a Revise and Resubmit on November 16th 2023.	This study has been pre-registered in OSF. Registration DOI: https://doi.org/10.17605/OSF.IO/TC65E
C	Beyond deliberation. Exploring perceptions and experiences of science (dis)engagement in England.	Under review in *Science Communication*. Received as Revise and Resubmit on January 22nd 2024.	This study received ethical approval by the Research Ethics Committee of Aarhus University on April 19th 2023. Approval number: BSS-2023-044.

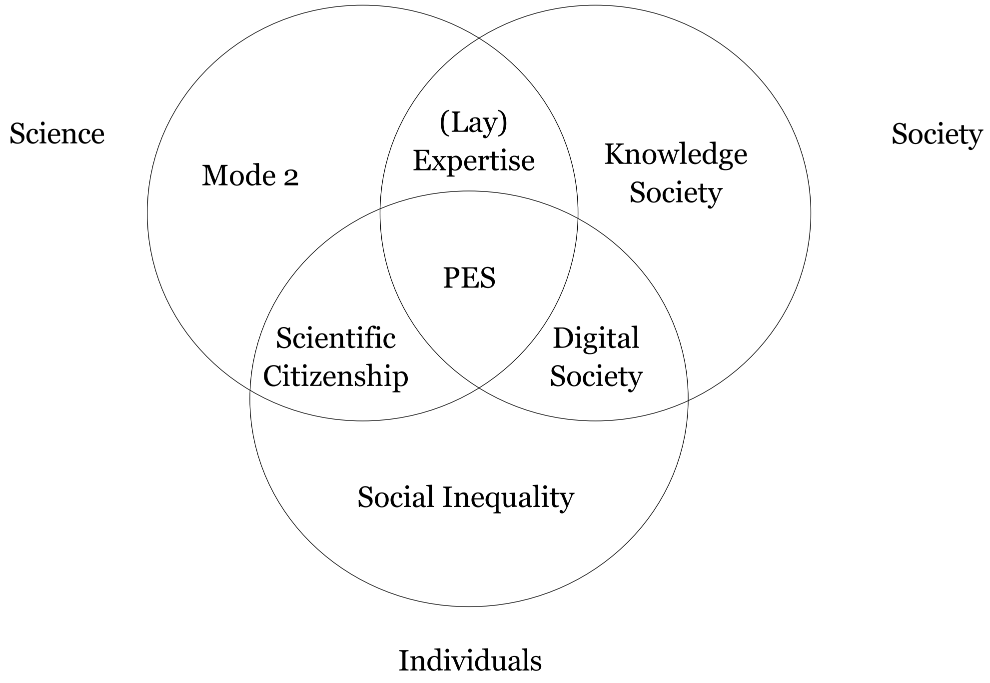
Finally, in chapter 7, I summarize the findings, and discuss their limitations and implications. The aim of this chapter is to show how the project addresses the main research question while deriving general points of discussion and contributions, beyond the specific empirical results. I describe how this study prompts reflections on three main areas: the definition of engagement and disengagement with science, the role of institutional responsibility of science, and the general democratic goals of Public Engagement with Science. I end the chapter by outlining possible future research avenues and drawing a general conclusion.

Chapter 2
Conceptual Framework

The discourse about public engagement with science in current Western societies is framed by a number of other features that relate to the structure of societies itself, the organization of science and the role of citizens. Public engagement with science is a tool to shape futures, but it is also a dynamic of social change, thus its understanding is necessarily linked to a broad discussion around elements of society in which it takes place. In this chapter I outline the theoretical themes and concepts that guided the development of this dissertation, from the formulation of the research questions to the analysis of the results. The concepts of Knowledge and Digital Society are introduced as central features to understand the modern context in which public engagement with science takes place. A discussion of Mode 2 of knowledge production, and (Lay) Expertise are useful to frame the status of science in this setting. In addition, the concepts of Scientific Citizenship and Social Inequalities are used to address the expectations for individuals regarding science in this context. Public Engagement with Science (PES) is then introduced together with relevant empirical literature to understand its relationship with the concepts described above. In the last section I will proceed with clarifying how these factors have been relevant in this study of public engagement with science.

Figure 2 is a visual representation of how a discussion of public engagement with science implies a reflection on the structure of society, the organization of science and the role of individuals, where each of these elements are related and interact with one another. In this chapter, science societies and individuals are described through their most relevant characteristics in relation to public engagement with science and are organized as shown in the figure. Clockwise, the concepts are presented in a descending order of abstraction, the definition of the markers of the modern social structure sets the scene for introducing the status of science, which is conducive to an elaboration on the conditions of the individuals in it.

Figure 2. Visual representation of the chapter's content



2.1 Society

Modern societies are characterized by significant developments, which interact strongly with changes in the organization of science and the role of citizens. Parallel with the spread of science and scientific authority, crucial elements are increased access to information, the expansion of education and the growth of individual empowerment and responsibility. These developments collectively contribute to what is commonly referred to as the cultural rationalization of societies, often encapsulated by the term *knowledge society* (Stehr, 2012). This transformation couples with the *digitalization* of societies, where the proliferation of readily available information and the importance ascribed to it potentially empower individuals to form independent opinions and integrate them into their daily lives. These changes had a notable effect on the science-society relationship and are at the heart of the new mode of knowledge production described by Gibbons and colleagues in 1994, introduced in section 2.2. The scope of the following is to introduce the concepts of Knowledge and Information Society and illustrate their relevance in a study of public engagement with science.

2.1.1 Knowledge Society

The notion of *knowledge society* is comprised of economic, organizational and cultural elements. Indeed, it describes a social setting in which knowledge increasingly represents a source of economic value, joining labor and property at the center of the economy structure (Stehr, 2012, for an overview see: Välimaa & Hoffman, 2008). This constitutes the focal point from which the significance of knowledge, and scientific knowledge especially, expands into other areas of society. In a discussion of public engagement with science, it is relevant to describe the concept of knowledge society as the product of a major cultural transformation that has unfolded in the last decades, fundamentally reshaping the relationship between science and society. Indeed, as observed by Stehr (2012), the conceptualization of knowledge in theories around modern social settings is often very narrow to include only scientific and technical aspects. This phenomenon is well captured in the concept of *scientization* by Meyer and Bromley (2013), who describe it as a process in which "scientific activity and ideology have grown and acquired authority" establishing themselves as an alternative base of legitimacy (p. 370). Indeed, scientization can be seen as the permeation of scientific principles throughout every aspect of society and are now held as a gold standard for their ability to provide an ordered framework in which to read the "chaos surrounding human life" (Meyer & Bromley, 2013, p. 370).

Examples of the pervasive influence of this narrow notion of knowledge can be found not in the extinction of movements disputing science, such as those arguing against anthropogenic climate change or favor flat earth claims, but in their argumentations. Indeed, these movements, over time, have given up their alternative narratives to embrace the language of science (Meyer & Bromley, 2013). Furthermore, in the context of policy making, scientization signifies the "growing reliance on scientific expertise to back up political claims and to draw up viable policy solutions" (Krick et al., 2019, p. 927). By grounding political decisions in rigorous scientific evidence, policymakers aim to develop more informed and well-reasoned solutions to complex societal challenges, ultimately contributing to the betterment of society. However, it is important to acknowledge that divergent viewpoints exist regarding the implications and desirability of this paradigm shift. In their thought-provoking work *Politics of Uncertainty*, Scoones and Stirling (2020) take a critical stance toward the prevailing rhetoric of progress in which science based evidence is held as a shield against irrationality. They contend that among the advantages, scientization also warrants scrutiny due to concerns about the uncritical prioritization of science and the potential marginalization of alternative forms of knowledge and wisdom. This same duality is present in the contemporary redefinition of science and scientific institutions presented in the next two sections and lays the groundwork for debates about opening the scientific structure to new actors. Indeed, among the features of knowledge societies there is the dissolution of the criteria for membership and the possibility for other members of the public to produce valuable input (Mejlgaard, 2009).

In this dissertation, knowledge society contributes to the positioning of public engagement within the broader societal context. Additionally, I employ this framework in seeking to understand how science and science representants are perceived among the population and in making sense of people's choice not to engage with the social discourse about science. Knowledge based societies are part of the overarching process of cultural rationalization mentioned above, in which rational and scientific come to share a lot of their meaning. Taking a step ahead, if participation in the scientific discourse is an individual responsibility and comes to be synonymous with rationality, non-participation appears inherently irrational. This dissertation takes a nuanced approach, delving into the intricacies of (dis)engagement and probing the underlying motivations that drive individuals to choose not to actively participate in the science discourse. This approach seeks to unfold the complexities of disengagement, shedding light on the multifaceted landscape of public engagement with science.

2.1.2 Digital Society

The advancement of technology, especially digital technology, is a core feature of modern societies as it implies a marked shift in the way individuals, institutions and societies operate. These technologies bring about a significant transformation of daily activities, but also lead to their presence as integral and pervasive parts of life. Digital technologies, new media and the internet facilitate global communication, revolutionize the way society is organized, and enable extensive and easy access to information. It is relevant to spend some time discussing this aspect of social transformation as its implications contribute substantially to the ongoing evolution of the relationship between science and the public. The aspect of most relevance in this discussion of public engagement with science is the opening of new participation avenues for the population.

The online environment has caught up with traditional media outlets to become one of the main sources through which individuals retrieve science news and information and where a good part of the debates takes place (Brossard, 2013). Moreover, among the online providers of information, social media are fundamental sources of science and technology news (Huber et al., 2019). Beyond offering extended outreach, these platforms have a powerful dialogic potential and are used to disseminate scientific insights while generating debates between science communicators and citizens (Dunn et al., 2015). Access to science debates is no longer reserved to science professionals or confined to formal arenas, but a wide range of interaction possibilities is available to the connected public. In this context, three different levels of user involvement have been observed: consuming, participating and generating (Taddicken & Krämer, 2021). While the first one, consuming, has always been typical of the public of science communication, the other two, participating and generating, are relatively new especially in the extent of their availability to the users. For the first time in history, the world does not end with every person's social network and engagement possibilities are not defined by the material that is physically available. This implies relevant changes in the meaning of science communication and public engagement with science (Taddicken & Krämer, 2021).

Nevertheless, it must be underlined that the days of undivided techno-enthusiasm for the avenues provided by digital platforms are long gone and the challenges that these instruments present have emerged strongly (e.g. Scheufele & Krause, 2019). One of these challenges is the redefinition of scientific experts nourished by the possibility for the public to switch from passive to active participant in the science debate (Bucchi & Trench, 2016). This feature has been described as part of the process of *democratization* of the debate on science issues (Bucchi, 2017) and as a challenge to the exclusive expertise of scientific experts (Collins & Evans, 2002), addressed in a later section. Other fundamental problematic aspects of digital media are in terms of differences in terms of access (first level digital divide) and usage patterns (second level digital divide) (Hargittai, 2002; Van Deursen & Van Dijk, 2014), which translate into inequalities across strata of society. Below, section 2.3.2 addresses the dynamics of social, economic, and cultural inequalities that are underlying this and other concepts presented in this chapter.

The digital and informational framework and the type of engagement possibilities that it carries have been both the point of departure and the result of the work included in this dissertation. From my intention to focus primarily on the sphere of digital engagement with science, I realized that additional essential and inherently preceding elements needed to be included into this reasoning on engagement. Nevertheless, the context produced by digital technologies continued to reemerge throughout my research, significantly influencing a substantial portion of the last empirical chapter. Digital and online media represent important sources and significant challenges to science communication and, at the same time, for public engagement with science. For what concerns political engagement, digital platforms have represented an important and contested field of research in the last decade. Concepts such as digital activism, political consumerism, and slacktivism (Christensen, 2011; George & Leidner, 2019) have been introduced to describe the variety of ways in which the relationship between individuals and political participation has evolved. In this study of public engagement with science, I borrow from this literature the instruments to describe the current relationship between science and the public and imagine alternative possibilities.

2.2 Science

As already introduced in the previous section, science is at the core of modern social change, and can be seen as both a driver and a product of such change. Moreover, deeply embedded in this is the new role that individuals as human beings and as citizens take on in these new settings. This section describes the changes that the system of science has gone through, by introducing the concept of *Mode 2 of knowledge production* (Gibbons et al, 1994). This describes the consequences that modern and transdisciplinary social and economic structures have on the way scientific knowledge is developed. Among the core features, there is the inclusion of the wider public in the process of knowledge production, which implies a reflection of the concept of *expertise*. Indeed, not only do scientists acquire a new and prominent status as experts in knowledge societies, but the idea of *lay expertise* is at times included in the way knowledge is understood.

2.2.1 Mode 2 of knowledge production

Gibbons and colleagues describe Mode 2 of knowledge production first in 1994 and enrich the argumentation in a smaller formation later in 2001 (Nowotny et al., 2001). I will base the following description of Mode 2 mostly on the book from 1994. Their work is seminal in the context of the sociology of scientific knowledge as it conceptualizes and elaborates on the complexities of opening knowledge production and policy development to new audiences. They observe that the changes that have taken place in modern societies have been so profound to have modified the way knowledge has traditionally been produced and propose an analysis with which to read and make sense of these trends.

To delve into the core concepts of Mode 2, it is necessary to clarify its meaning in contrast to Mode 1. Mode 1 of knowledge production refers to the understanding of sound scientific practice in the most traditional way, it could be said that it aligns with the common definition of science: “It’s cognitive and social norms determine what shall count as significant problems, who shall be allowed to practice science and what constitutes good science” (p. 3). The same of course happens for Mode 2 of knowledge production, but these social norms and practices are profoundly different. Indeed, while Mode 1 is developed in a disciplinary cognitive context, Mode 2 is characterized by being developed in a transdisciplinary socio-economic context. To remark the distinction, the authors refer to the actors and the products of Mode 2 as practitioners and knowledge and not anymore as scientists and science. The book elaborates on the meaning of Mode 2 for several fields of science and many aspects of the scientific production process, and it is not possible or necessary to mention them all in this review. In this chapter, I focus on the core concept of context of application to outline the elements of Mode 2 that are of major relevance in a study on public engagement with science.

Central to understanding the paradigm shift that Mode 2 implies is the concept of *context of application*. The authors employ this idea to describe the empirical and applied character of the new production of knowledge. This always takes place in answer to a need, and it is always related to the interests of some actors, Mode 2 knowledge is "intended to be useful to someone" (p. 4). However, this is not to be understood solely in a market framework of commercial considerations. Indeed, this new knowledge is intended as "socially distributed" and society in general is included among the stakeholders to the same extent to which industry, market and government are. Nevertheless, it must be noticed that despite society being considered on equal terms with the other interest groups, its role is mostly discussed in relation to disagreement and accountability demands. This is an indicator of the discrepancy between aspirations and implementations that characterizes, although with good reasons, elaborations in this research field. The shifts implied by the concept of *context of application* concern the production of all knowledge, including cultural productions, and the institutional setting in which the knowledge is produced. Universities and teaching institutions witness a shift in their mission, social profile, content, and outcomes. Teaching becomes research based, the research approach from free inquiry moves towards problem solving, industry becomes more incorporated in the strategies. It is relevant to mention these changes here because they happen in the context of digitalization and massification of education and higher education introduced above. However, the authors describe that despite the possibility offered by the information technologies to transmit information without time or space constraints, the inequalities among countries and areas of the world in abilities to engage in research and use it keep existing.

Finally, this new configuration of knowledge production and use occurs alongside the institutional reconfiguration of higher education. I have already introduced how universities, still the central institutions of knowledge production, are affected in their core elements by the implications of Mode 2. One of the essential features of the transformation of universities in knowledge industries is their change in function and the role of transdisciplinarity. Issues of science and technology that do not include social elements in their development are part of Mode 1, characterized by disciplines with clear boundaries and goals. Mode 2 is defined, instead, by the blurring of the delimitations among disciplines, or better, among the appropriate approaches to new issues.

Cooperation between experts from different disciplines to work on a single and temporary research project becomes necessary and usual for all technical, natural and social sciences. The transdisciplinary character of Mode 2 does not only imply collaborations among scientists from different backgrounds, but the wider public is included in the process of knowledge production, which introduces the theme of expertise discussed in the next section. In the words of the authors (Gibbons et al., 1994, p. 148):

> As more and more aspects of life in society are perceived to involve issues having a techno-scientific dimension science cannot be left to scientists alone. The methods and techniques of knowledge production in Mode 2 have become important ways to investigate societal issues in which many individuals and groups have some stake. [...] The issues are essentially public ones, to be debated in hybrid fora in which, there is no entrance ticket in terms of expertise. In such a participatory science, the goal is no longer truth per se, but responsible public decision making based upon understanding of complex situations where many key uncertainties remain to be resolved.

The relevance of this framework in this study of public engagement with science is now straightforward. In a Mode 1 context, introducing non-scientists in the process of science would be almost unthinkable or, at least, it would challenge many of the fundamental structures on which science is built and maintained. In a Mode 2 context, instead, envisioning a variety of applications of public engagement with science is possible and easier. This perspective on science and society developments is embraced in the understanding of the current deployment of engagement conceptualizations and practices. One of the core aspects of this original formulation of Mode 2 is that for what concerns the quality control of the knowledge production process, guiding principles are reflexivity and social accountability. By applying this concept throughout this study, I wish to understand to what extent do current conceptualizations and applications of public engagement with science answer that call.

2.2.2 (Lay) expertise

In the same years that Model 2 of knowledge production was being developed, a new understanding of the public's contribution to scientific decision-making emerged. The lay expertise model (Lewenstein, 2003) considers the contextual point of view of the members of the public as a central element in science-society relations, which not only is to be acknowledged but most importantly should be incorporated into decision making. The public is not to be considered as a homogeneous entity, but to different science issues and in diverse contexts, various types of *local public* of science exist (Wynne, 1995). The goal of this new stream of studies was not to push relativism or glorify alternative knowledge, but to spark a conversation on the positive role that the implementation of reflexivity in science and technology development can have on science–public trust (Jasanoff, 2003).

The study that can be considered as representative of this turning point in the conceptualization of the public is Wynne's (1996) case study of Cumbrian sheep farmers and their reactions to the restrictions imposed them upon scientific advice after the Chernobyl radioactive incident. The study shows how the lack of reflexivity and self-criticism among science representatives who ignored the local expertise of the farmers contributed largely to an incorrect assessment of the situation by the former and mistrust among the latter. Moreover, the study exemplifies the contribution of public participation in decision making over science related issues. Indeed, as Collins and Evans (2002) observe, the local farmers did not contribute with scientific expertise, which they did not have, but they provided local knowledge, which turned out to be as valid and relevant as the scientists' knowledge. This taps into the distinction made years later by the same Wynne (2007) between technical issues and public issues involving technical experts (p. 108). In an attempt to clarify his position, the author argued that indeed it is only in the second case that the public perspective should be called into question, to discuss around larger issues of "what research questions come to be seen as salient, with what imaginations of human ends and possible outcomes" (p. 106). Indeed, a few lines below he mentions:

> I have never heard any such advocates suggesting that we need 'democratic involvement' in deciding what factors influence alternative splicing in gene–protein relationships, or in anything of the kind. Nor do they claim public qualifications in such specialist expertise. This red herring should be dispatched forthwith.

This mismatch in the definition and expectations of the public's contribution in science debates is central in discussions of lay knowledge and led Collins and Evans (2002) to their elaboration on what they labelled as the *third wave of science studies,* which focused on clarifying the boundaries between experience, expertise, and political rights. Introducing this literature would necessitate a lengthy discussion outside the scope of the current discourse. It is enough to say that the goal of a revisiting discussion of the concept and role of expertise is not meant here as an expansion of the concept itself or aimed at equating non-scientific and scientific knowledge. In search of better words, I borrow those of Stilgoe, Irwin and Jones (2006, cover page and p. 40) to frame the implications of the shift in perspective for science policymaking brought about by the inclusion of lay expertise in the process: "The challenge is to embrace different forms of expertise, to view them as a resource rather than a burden". They argue for overcoming the "expert vs public debate" and abandoning the idea that 'opening up' (Stirling, 2008) decision-making processes would undermine scientific expertise. On the contrary, they argue, this would enrich decision-making possibilities by uncovering new problems and questions to be addressed, which would otherwise be invisible to a crowd of only scientists. Davies and Horst (2016, p. 191) take up this reasoning to argue the importance in terms of legitimacy and efficiency of the inclusion of public perspective in sociotechnical developments, even, or especially, when in contrast with experts' opinions. Indeed, the authors highlight the fact that individuals that resist and debate science are in fact actively engaging with it and should not be ignored. In their chapter, the authors introduce the question of lay expertise, informal civic engagement, and power to reflect on the concept and the applications of scientific citizenship, which is discussed in the next section.

An introduction of the concept of lay expertise and the academic standpoints on it is useful here to understand the discussions within which public engagement with science is located. The intuition that the public might hold resources that could complement or interact with official and certified scientific knowledge is at the source of the development of public engagement with science. This concept is also important because it implies a change of perspective in the relationship between science and the public, led by the curiosity of understanding how reality is perceived outside the realm of scientific authority. Abandoning the hierarchy of knowledge to embrace the possibility that different contributors could bring different kinds of expertise (Lidskog, 2008) to understand the world is among the leading principles of this exploration of public engagement with science.

2.3 Individuals

The last dimension of public engagement with science to be introduced is the focal one of the individuals. *Scientific citizenship* is introduced to describe the new role of citizens in modern knowledge societies. In a context where scientific knowledge is pervasive and access to scientific information is, or should be, made easily available by digital technologies, citizens' rights and duties expand to include science as both being well informed and taking part in deliberative activities regarding science related issues (Mejlgaard, 2009). At the same time, a discussion about the rights and duties of citizens in modern societies would be incomplete without taking into consideration one of the fundamental determinants of people's life course and actions: *social inequality*. Public engagement with science and the concepts introduced above rely on social, economic and cultural factors, hence among the various determinants of individuals positioning in society, here social inequality is defined as the one underlying them all.

2.3.1 Scientific citizenship

> The notion of scientific citizenship (Irwin 2001) points to an increasing awareness of the intermingling between science and society. It implies not only that scientific knowledge is important for citizenship in contemporary society but also that citizens can lay a legitimate claim about accountability on scientific research. As such, the notion can be perceived as a normative ideal concerning the appropriate form of democratic governance in a society that has become increasingly dependent on scientific knowledge (Horst, 2007, p. 151).

This is one of the most recurrent definitions of *scientific citizenship* that emerged in the late 1990's, when the concept of deficit started to interact with the one of deliberative participation. Indeed, as captured by Mejlgaard and Stares (2010), the quotation suggests duality in the concept of scientific citizenship which includes both being well-informed about science and taking part in deliberative activities. The notion of scientific citizenship describes the new role of citizens of the previously introduced modern knowledge societies, characterized by the ubiquitous presence of science embedded in the social fabric (e.g. Irwin, 2001). Thus, in this new context citizens' rights and duties expand to include science.

Among the rights, citizens should "be informed, by means of appropriate dissemination schemes, about the developments, potentials, and risks alike in science and technology in order not to be marginalized from social systems" (Mejlgaard & Stares, 2010, p. 547). However, being informed without having granted the possibility to "speak back" to science (Gibbons, 1999) is not acceptable nor sufficient anymore. The second right that the scientific citizen should receive is the insurance that their "concerns are in fact fed into decision-making processes" (Mejlgaard & Stares, 2010, p. 548). That is, besides receiving the necessary information to be an informed citizen of a modern society, they should be granted access to democratic participatory and deliberative processes which would actually consider public input on science-related issues. Beyond being new rights, information and participation are also considered new duties of the scientific citizen.

Following a "republican" ideal of democracy, the authors of the study referenced above argue that to achieve a "full citizenship", people are required to "not simply enjoy the right to enter the sphere of decision making, but rather actually entering it" (Mejlgaard & Stares, 2010). This might be the most controversial aspect of the notion of scientific citizenship and the part that has been contested the most by other researchers. The same authors in a later analysis of the concept, re-align their approach to understanding this concept to a more “liberal” ideal of democratic participation in which the emphasis is on “individuals interests rather than civic responsibilities, and opportunities for participation rather than obligation to participate” (Mejlgaard & Stares, 2013). Around the same time, in a discussion of Icelandic biopolitics, Árnason (2013) proposes a critique of the emphasis on the ideas of active citizenship and public participation, arguing that the importance of public accountability, another fundamental aspect of deliberative democratic theory, is overlooked. Árnason recognizes the importance of the involvement of informed and active citizens in policy making. The author underlines the role of democratic institutions in making sure that citizens are provided with the means to achieve these goals, but also highlights the role of good governance as a necessary condition for the above to take place effectively. Indeed, without necessarily proposing a reconciliation between these two points, Árnason argues for the focus to be “turned towards the institutions that are the venues of democratic decision making and to a critical investigation of the practices of accountability and justification” (p. 938).

The concept of scientific citizenship, together with its various critiques or refinements elaborated over time, has played a central role in shaping the foundation of this study. It constitutes an important instrument through which to understand and interpret the role of citizens in modern societies. Most often, the concept of scientific citizenship has been applied in a top-down manner, with limited consideration of the perspective of the general population. This study adopts a blended approach to scientific citizenship. It integrates its conceptualization and framework in the way research goals are formulated and investigates how individuals perceive their role within society, aiming to assess the alignment of these perceptions with the established concept of scientific citizenship. This approach aims at a nuanced and enriched exploration of scientific citizenship that takes into consideration individual perspectives of possibilities and preferences.

Lastly, an unresolved aspect of the application of this concept that is worth mentioning in this discussion of scientific citizenship is the lack of problematization of the non-homogeneity of the public and the possible differences in uptake and resonance of the participatory framework among different types of public. In a study on performed and preferred participation, the authors observe in their argumentation that (Mejlgaard & Stares, 2013, p. 661):

> while deliberation organizers often conceive of the participating ‘ordinary’ citizens as demographically reflecting the population, lacking science and technology background, and having no advocacy position towards issues in question, in fact they tend to be comparatively more alert and aware, with higher

> incomes, more liberal orientation, and comparatively better educational background than the average citizen (Powell et al 2010).

This caveat is relevant when understanding the role of scientific citizens and exploring participation possibilities, as the composition of the active citizens matters for whose perspectives and interests get represented in deliberative discussions. This observation is interlinked to the next and last concept that is introduced in this chapter: social inequality.

2.3.2 Social inequality

The spread of science and technology in society and decision-making has inevitably intersected with pre-existing social hierarchies and disparities, which have both persisted and, at times, undergone redefinition. To conclude the conceptual framework that guided this study of public engagement with science, it is necessary to address the role of social inequalities within the realm of science in society. To better understand these interactions, it is essential to establish situated definitions of key concepts like social class and stratification within the context of public engagement with science.

Social class. Either defined in strictly economic terms by labor status and ownership of the means of production, following Marx, or including dimensions such as social prestige and political influence, as for Weber, the concept of social class at large refers in these terms to a group of people sharing a similar experience of the world (Ritzer, 1996). The way in which the communalities defining the boundaries of the groups of people have evolved over time, have determined various understandings of social class, and in recent times even its *temporary death* (Clark & Lipset, 1991; Van der Waal et al., 2007). In the present study, the concept of social class is a useful reminder of the situatedness of people's own perceptions of science and engagement with science. Therefore, here social class is understood as the heterogeneous set of economic, cultural and social experiences through which individuals live their daily life, aligning to Bourdieu's multidimensional understanding of the concept (Bourdieu, 1986).

Social class and related concepts have already entered the research arena of public engagement with science and have been used to study this concept from new points of view. Especially interesting to mention here is the concept of *science capital* (Archer et al., 2015), a re-formulation of Bourdieu's (1986) forms of capital that considers science-related resources as a contemporary form of capital. The authors propose a definition of this capital as a combination of three elements: scientific cultural capital, defined as scientific literacy and attitudes; science-related behaviors and practices, defined as activities of engagement with science; and science related social capital, defined as social proximity to science. It might be easy to spot similarities between the concept of *science capital* and *scientific citizenship* introduced above, especially in the consideration of literacy and engagement as joint core elements. While scientific citizenship serves as analytical tool to understand rights and duties of the modern democratic citizen, science capital serves as a lens over the socio-economic differences and consequences of certain science dispositions and practices. Indeed, this science specific form of capital, the authors argue, is similar to the other forms of capital for it can be equally exchanged for services and advantages within society, influencing individuals' life outcomes.

As a final remark, it is important to underline that social class is, in sociological terms, a *social construct*. This means that it is not an intrinsic property of individuals, but it is nevertheless strictly related to the way they make sense of the world and act in it. Social classes can be generally defined as "structures that are external to, and coercive of, people" (Ritzer, 1996). Indeed, these extrinsic individual characteristics interact with the environment in which individuals are immersed, leading them to act in certain ways according to certain beliefs, rather than others. In this regard, the concept of social class is closely related to the one of stratification.

Stratification. In sociological terms, social stratification is the organization of social groups based on wealth, status and power present in most societies. This organization is hierarchical and creates unequal access to resources and opportunities, leading to differing social privileges and life outcomes. Social class is only one of the dimensions on which stratification is built and inequalities are produced. Other elements can be age, gender or ethnic origins, and their combination determines individuals' positionings on the social scale (Giddens & Sutton, 2021). What is relevant to underline here is that the differences operated among members of societies by this classification can be produced, reproduced and reinforced through the forms of capital introduced above (Bourdieu, 1986; Bourdieu & Passeron, 1990). This is especially clear when it comes to cultural capital. Indeed, some forms of cultural participation, e.g. educational systems, provide certain social groups with resources they can convert into wealth and power, while for those who are left out of these systems it is harder to access such benefits (Bourdieu & Passeron, 1990). Differences in access to these systems intersect with the fact that different cultural forms practiced by various social groups are recognized and valued differently according to which group they are traditionally associated with (e.g. see Bryson study of music taste, 1996), which has consequences for which (and whose) practices are given relevance and recognized as valid.

In this dissertation, understanding engagement with science as a form of capital and a cultural practice modelled by social dynamics requires a change of perspective and allows the investigation of new questions. The fact that the public is not a homogeneous entity, but an ensemble of various social groups interacting differently with society and science, has consequences for how engagement is conceptualized and practiced. This perspective is fundamental in understanding how this variety of practices can be included in the conceptualization of engagement and exploring the consequences of doing so. Existing research on public engagement employing a similar perspective focuses on the socio-economically and racially marginalized groups of the population (e.g. Dawson, 2019; Godec at el., 2018) and paints a complex picture in which everyday contexts, social hierarchies and practices of engagement all contribute to enabling or limiting individuals' engagement with science. The present study is informed by this approach while proposing an additional perspective. Here the stratification of social groups according to their class and their capital is used as an underlying analytical tool to explore in paper 1, to explain in paper 2, and to understand in paper 3, engagement with science practices. Specifically, the aim is to unveil the capabilities of alternative ways of relating with science outside of the usual, formal and institutionalized conceptualizations of engagement with science activities.

2.4 Public Engagement with Science

This section includes a brief review of the empirical academic literature on definitions, goals and explanations of public (dis)engagement with science. The available definitions are numerous and contextual, and present a wide focus on redistribution of decisional power, while little space is dedicated to other conceptualizations of engagement with science. This translates into a similarly narrow focus on the goals of engaging the public with science. Active deliberation is certainly a core feature of democratic societies and as such, and it is the focus of much of the academic literature of public engagement with science. Nevertheless, there are emerging perspectives arguing for the exploration of a broader impact of science on individuals' lives within the engagement with science discourse. It is relevant to highlight such hierarchy among the goals of engagement for it is relevant to understand the disengaged population and their attitudes. The longstanding representation of the public as inherently predisposed to engagement with science means that disengagement is often reduced to a mere lack of outreach. The main explanations of science disengagement present in the literature are introduced together with underdeveloped paths. Finally, I discuss how disengagement intersects with individuals' socio-economic and cultural status, which are crucial characteristics of the social positioning.

2.4.1 Defining Public Engagement with Science

Public engagement with science encompasses a variety of activities that share a rethinking of the process of science communication in which the audience is not only understood as an active listener but becomes an integral part of the scientific process itself. Indeed, in the first descriptions it is referred to as, e.g., the co-production of science model (Callon, 1999), or the public participation model (Lewenstein, 2003). These perspectives refer to different types of interaction between science and the public, which would be later operationalized into the broader concept of public engagement with science. Indeed, Callon's (1999) definition and reasoning focuses on the involvement of "the lay people in the creation of knowledge concerning them". Here the emphasis is on elements like the new role of the public as a "concerned group", the "collective learning" that is enabled by the new perspective of knowledge exchange rather than delivery, the "common enterprise" that is at stake in the exchange rather than one actor's trust in the other. The latter represents a fundamental change in the envisioning of the science-society relationship that motivates only part of the subsequent efforts of public engagement with science. The public participation model described by Lewenstein (2003) revolves around the "commitment to democratizing science – taking the control of science from elite scientists and politicians and giving it to public groups through some form or empowerment and political engagement" (p. 5). Thus, included in this definition of participation there are solely activities as "consensus conferences, citizen juries" aimed at providing avenues for decision-making. The reasoning behind this model focuses on the relevance of public trust in science, which is expected to waver less easily when the public is included in the decision-making process on scientific issues.

Both conceptualizations of public participation, later grouped under engagement with science, entail a challenge to traditional democratic institutional arrangements, such as the distinction of roles between political and technical expertise or public and professionals (Weingart et al., 2021). Nevertheless, this concept did not develop in a traditional science setting, but in a context of knowledge societies and Mode 2 of knowledge production. In this context, the public is invited to take part in science development and decision making on science related issues and contribute with lay knowledge and expertise relevant to the specific situations. Indeed, much of the existing characterization and typologies of public engagement with science revolve around the extent to which the public shares decisional power (Arnstein, 1969; IAP2 Spectrum, 2018), directs the flow of information (Rower & Frewer, 2005) or participates in knowledge creation with scientific institutions through more and less spontaneous activities (Bucchi & Neresini, 2007). These typologies are theoretical representations elaborated by scholars of how the public could or should engage with science so that decision making can be more inclusive and representative. A problematic aspect of these theoretical mappings is that they all depict a hierarchical picture of public engagement (Schrögel & Kolleck, 2019). Engagement opportunities are ranked according to the dimensions around which these typologies are constructed, which represent the core elements and normative values of the first elaborations of public engagement with science. Indeed, underlying them all is the assumption that the best engagement is aimed at including the public in the process of decision-making, possibly attaining maximum sharing of power, highest levels of co-creation and bidirectional flow of information.

A recent typology of engagement with science activities marks a breaking point regarding the assumptions underlying previous mappings. The participatory science cube (Schrögel & Kolleck, 2019) takes into account the multidimensionality of engagement and the equal legitimacy of activities involving various types of public and offering different levels of inclusion of the public in science beyond governance and knowledge generation. The authors describe this tool as useful to map various forms of engagement without the "normative mandate to push all participatory approaches to the outermost corner of maximum openness" (p. 95). Indeed, this instrument represents a step forward towards the legitimation of alternative forms of engagement that lie outside the formal perimeter of deliberative and co-creative participation. This push for widening the established space to include other ways of categorizing engagement remarks the rationale around Wynne's (2007, p. 107) distinction of *invited* and *uninvited* forms of public engagement with science. The importance of equally acknowledging both forms of public engagement relies on the recognition of the link between the framework and the core goals of engagement. Before moving on to discussing these goals, which are intrinsically related to conceptualizations of engagement, the next paragraph will turn to the definitions of engagement with science in empirical academic research.

When it comes to empirical definitions of public engagement with science, a recent review of the literature (Weingart et al., 2021) suggests that this concept is used in a contextual and adaptable manner. The authors review academic research relative to engagement with science and highlight that it is defined according to various characteristics: its objectives, the intended audiences, the role of the public, the nature of the science-public relationship, or the types of activities. Combinations of these indicators produce definitions of public engagement relative to the situation they are applied to. Additionally, a distinct part of the literature on engagement with science consists of research on citizen science, a modality of engagement focused on the "public's collaboration in research" (Delicado, 2021). Definitions and applications of citizen science are equally varied (Schrögel & Kolleck, 2019), and the common trait is the inclusion of non-professional researchers in the generation of knowledge. A criticism that is often moved towards characterizations of citizen science is that the public's collaboration is seen only as consisting of data collection (Delicado, 2021). While this may sometimes be the case, instances in which the public is invited to shape, direct or create research projects exist and can potentially contribute significantly to scientific development (Shrink et al., 2012). Research has investigated various aspects related to citizens' participation in the production of knowledge, such as people's motivation to join such activities (Domroese & Johnson, 2017) or attitude change generated by participation (Dean et al., 2018; Yanco et al., 2021). Nevertheless, the relationship between this practice and other engagement initiatives needs to be further understood.

2.4.2 Goals of Public Engagement with Science

In discussing public engagement with science, the intended objectives play a pivotal role in shaping the various forms of engagement. Indeed, both empirical definitions and normative reflections on engagement typologies are driven by understandings of the goals of engagement with science, e.g. educate and inspire the public, legitimate and democratize science (Weinigart et al., 2021). Focusing on objectives not only aids in interpreting traditional approaches to public engagement, but it also facilitates a fruitful discussion about the potential of emerging and less established activities of engagement with science. The importance of aligning goals with engagement activities has been highlighted already by Glass (1979). In building a description of participatory programs, Glass put particular emphasis on a detailed elaboration of the goals of engagement. The argument standing that if the ultimate goal of engagement activities is *citizen participation*, then "any technique will suffice as long as it is categorized as a participatory device". Nevertheless, it is worth noting that Glass primarily referred to engagement related to government decision making, one of the key purposes for which public engagement with science was elaborated.

As already highlighted at the beginning of the previous section, formulations of public engagement with science have revolved around two central loci of citizen participation: decision making around science-related issues and co-creation and development of scientific knowledge. These two instances have evolved into different practical modalities of engagement. Consensus conferences, citizens assemblies, or deliberative workshops (e.g. Danish Folkemødet[2]) have been aimed at including the public's perspective into government decision making over science and technology related issues (Delicado, 2021). Initiatives of citizen science, from gathering of science related information to more substantial involvement in scientific projects, have been aimed at making science and technology development more responsive to public demands and needs (Delicado, 2021). Nevertheless, both these modalities are produced by and share the same deliberative framework, which also underlies the concept of scientific citizenship. Indeed, theories of deliberative democracy as a free, reasoned and equal process aiming at consensus around rational policy results (Habermas, 1975; Cohen, 2009) have been underlying much of the academic discussion on public engagement with science (Davies, 2015; Davies & Horst, 2016). Some of the critiques of the emphasis in academic debates of public engagement on this definition of deliberation (e.g. Árnason, 2013) have been introduced in previous sections. Sturgis (2014) adds two points regarding the methodological shortcomings of the practice of engagement following this paradigm. One regards the conciliation of the ideal of engaging the whole population in invited deliberative activities with the necessary drawbacks of being able to involve only a (hardly) representative sample of the public. The other concerns engagement researchers' "lack of critical reflexivity" (p. 40) in that the idea of involving the public in decision making is the best way to include public's perspectives in the development of science policy was never questioned. This critique, he argues, is aimed at highlighting the need to elaborate further ways to achieve public responsibility of science development.

It is worth mentioning that underlying both main goals of enhancing decision making and science development, the core aim has been to enhance general positive attitudes towards science. Indeed, the fundamental assumption that accompanied the birth of the public engagement with science paradigm is that proximity to science would translate into enhanced trust in science (Wynne, 2006; AAAS, 2016). Several arguments could rightly be made for framing this perspective as reasonable, given the central place of science in knowledge societies and the relevance science and technology developments have for individuals' lives (e.g. vaccines, covid-19 safety measures). Nevertheless, the application of this principle becomes problematic the moment it implies a unidirectional acceptance of science and technology among the public and the dismissal of their concerns by science. This recalls the core

[2] Dall, M., & Pedersen, M. H. (2023). Denmark's big tent includes postdocs. Science, 380(6641), 143-143.

assumption of the first initiatives aimed at enhancing public literacy with science: to know science is to love it (Irwin & Wynne, 1996). In a rather critical paper on the premises and assumptions of public engagement with science, Wynne highlights the problematic implications of uncritically and tacitly applying the *deficit model* (Irwin & Wynne, 1996) to processes of public engagement with science. The central point of this critique is that applying engagement with the ultimate goal of convincing the public of the trustworthiness of science prevents science from being able to acknowledge reasons for public concern and from evolving in a responsible and accountable way.

Empowering the public to increase their influence in decision making on science related issues is a guiding aim of established activities of public engagement with science aiming at enhancing public trust in science. However, new emotional and material aspects of the relationship between science and the public have been highlighted in science communication research. In this regard, it is relevant here to mention reflections on the experiences of amusement and delight by the participants of science related activities by Davies (2015). In a book chapter titled "science as pleasure", Davies makes the case for an exploratory aim of communication and engagement research towards understanding, rather than designing, the variety of ways in which the public interacts with science and how informal activities might translate into deliberative interests. To motivate attention to alternative forms of engagement such as those introduced above, Davies contends how personal enjoyment is not limited to individual pleasure, but the "potential for public good" (p. 171) hidden in some informal activities can significantly drive personal involvement. This perspective differs from those with trust as the ultimate goal mentioned in the previous paragraph, in that it is necessarily open to diversity and disagreements. Indeed, expressions of differences of opinion may be understood as engagement with science (Davies & Horst, 2016) and represent the unpredictable space in which new practices can be formulated (Davies, 2022).

2.4.3 Motivations for science (dis)engagement

Studies of science communications on people's motivations to take part in initiatives of engagement with science tend to focus on the already engaged public (e.g. Evia & Peterman, 2020). Indeed, this population is easily reachable, and relevant for understanding the personal drivers of engagement and are fundamental in informing existing practice. Examples include studies on the reasons and the gains of the participants in science festivals (e.g. Jensen & Buckley, 2014; Rose et al., 2017; Jensen et al., 2021) or activities of citizen science (Edwards et al., 2018; Paleco et al., 2021). Science festivals are "a method of informal science learning that has been defined as a celebration of science, technology, engineering, and related areas" aiming to engage the public on a recurring basis and across varying themes (Evia & Peterman, 2020, p. 69, summarizing Bultitude et al., 2011). These studies often find that the types of public engaging in these activities are already interested and positively disposed towards science (Jensen & Buckley, 2014). For what concerns the outcomes of their participation, the most frequent is increased interest towards the topic treated, but emotional outcomes as pleasure, entertainment are at times considered as well (Jensen & Buckley, 2014; Davies, 2019). For what concerns knowledge, results are mixed for short- and long-term gains and may vary according to the level of relevance and social contestation of the core topic (Rose et al., 2017; Edwards et al., 2018; Peter et al., 2021).

Moreover, these practices have often addressed the public as a single group without reflecting on the impact of social, cultural, and economic characteristics of its members. The consequences of this approach can be seen in studies reporting the characteristics of the public engaged in these activities. Indeed, the engaged members of the public are often highly educated, belong to medium-upper income groups, are part of ethnic majorities and predominantly males (Jensen & Buckley, 2014; Jensen et al., 2021; Paleco et al., 2021). These same results appear across different forms of engagement such as deliberative or cultural activities or museums (Dawson, 2014a). These socio-demographic disparities in engagement with science are well documented (Judd & McKinnon, 2021) although research on the underlying mechanisms is not as detailed. Studies investigating the drivers of scarce engagement with science have traditionally focused on individual-level explanations. Lack of time, awareness, resources or interest have been presented as *barriers* preventing certain parts of the public from engaging in science-related activities (e.g. Charlton et al., 2010; Dawson, 2014b; Dreyer et al., 2021). This approach to understanding disengagement has been criticized especially in the last decade for providing a descriptive, static and oversimplified picture of science disengagement, without pursuing in a deeper understanding of the functioning of disengagement with science (Dawson, 2014b). Dawson (2014b; 2019) describes this framing as assigning the excluded public both an attitudinal deficit, for their lack of interest in science activities, and a behavioral deficit, for the key to their inclusion is the simple removal of the barriers. This approach is argued to be counterproductive in the quest for inclusive engagement as it locates the source and possible solutions of disengagement with the public, avoiding questioning the existing practices of science communication (Dawson, 2014b) which would benefit from more reflexivity.

A limited number of studies in science communication and education have moved the attention away from individual deficits, towards considering the structural and institutional contributors to disengagement with science among some parts of the population. Examples are Dawson's (2018; 2019) research on feelings and realities of social exclusion from science museums among marginalized portions of society, especially low income and minority ethnic groups and Godec and colleagues' (2018; 2022) work on engagement with science among students and young adults. Investigating the role of structural inequalities and social stratification, these studies observe that the marginalized public engage with science through a limited number of activities, often science media consumption, and highlight the role of feelings of cultural marginalization and powerlessness in motivating their exclusion. Beyond these studies, the production or investigation of social theories to understand class-based disengagement with science is almost absent. Theories that explain the disaffection with participation among certain social groups have been developed in the neighboring field of political participation, such as system justification theory (Jost and Banaji, 2004) or technocratic tolerance (Lindstam, 2014). However, these have not yet been systematically applied and tested in the context of public engagement with science.

Finally, it is worth mentioning that although these latter perspectives take into consideration the role of structures of society and science communications for the exclusion of marginalized populations from science, they do not question the type of practices included in the definition of engagement. A last perspective worth mentioning in research on political participation is the recent revival of the explorations of alternative forms of engagement among the population. A couple of recent studies investigate the existence and relevance of forms of informal and online participation among marginalized communities (Carrel, 2023; Kaskazi & Kitzie, 2023). Beyond the specificities of the forms of engagement analyzed, these studies explore the transformative potential of alternative forms of engagement. In doing so, they advocate for a broader perspective on participation, urging an exploration of the significance of seemingly small and unstructured participatory acts. However, the engagement potential of these activities in translating into wider engagement is uncertain and these activities' role in mitigating participation inequalities has already been questioned (Stolle & Hooghe, 2011).

2.5 Summary and research questions

In this chapter I have outlined the main concepts that guided the choices I have made to develop the discussion of public engagement with science included in this dissertation. Public engagement with science is about and involves different actors and levels of understanding. Indeed, it regards the behavior of individual citizens and influences the development of science while being immersed in the modern social context. Figure 2 at the beginning of this chapter is a visualization of these interrelations which I now summarize.

Current western societies are characterized by the pervasiveness of scientific knowledge, which permeates social and individual lives and represents an additional and fundamental basis for legitimacy (Stehr, 2012). With such an expansion of the authority of scientific knowledge, another characteristic of the scientific system in these societies is the new status and meaning of expertise. Indeed, beyond the more recurrent consultations of scientific experts by decision-makers, both these actors have started to acknowledge the importance of the perspective of the public and their lay expertise when it comes to social issues related to science or science development (Wynne, 2007). This element of novelty is well described by the new mode of science knowledge production, centered around transdisciplinary collaboration among researchers and including the public (Gibbons et al., 1994). In these knowledge-based transdisciplinary societies, citizenship assumes a new role which presumes expanded rights and duties of information and participation in deliberative activities (Mejlgaard & Stares, 2010). However, as shown by empirical studies, the concrete realizations of citizens' rights and duties interact with their social status and roles. Individuals' situatedness in society has a fundamental role also for their relationship with science (Dawson, 2019). Even a crucial feature of modern societies such as the widespread use and presence of digital and online media, which provides enhanced possibilities of participation and engagement, must be analyzed considering social inequalities in access and usage styles (Hargittai, 2002). Going back to Figure 2, this conceptual framework builds around *public engagement with science*, which has then been defined by its contents, goals, and motivations in the last subsections.

All three levels of concepts included in the current discussion of public engagement with science, individual, social and science, are crucial in setting the scene for the argumentations included in this dissertation. Nevertheless, the empirical work of which this elaboration is composed investigates the central concept from the point of view of the members of the public. As mentioned in the introduction, I focus on the *public* in public engagement with science, to understand how and why they understand and practice it. Indeed, as for the academic literature introduced above to describe definitions of engagement, typologies of the public are mostly focused on attitudes and opinions of science (Pullman et al., 2019), and those concerned with engagement with science are theoretical (Schrögel and Kolleck, 2019) or related to specific contexts of application (Weingart et al., 2021). This is a shortcoming in understanding how the public interacts with science and may have important consequences for the production of engagement initiatives. A deficient understanding of the engagement audience might lead to a lack of awareness of the determinants and characteristics of engagement practices. Addressing this concern represents the starting point for this dissertation, as it provides an empirical description of the public according to types of engagement and related socio-demographic characteristics. This exploration is described by the first research sub-question:

How can citizens be defined according to their engagement with science?

A second concern addressed in this dissertation concerns the motivation(s) underlying people's (dis)engagement with science. As described in the previous section, academic literature has scarcely addressed this issue. Empirical studies investigating reasons not to engage with science are not numerous, especially when it comes to making sense of the socio-economic disparities in engagement with science. At the same time, when it comes to attitudes towards science, empirical research is more extensive. Science attitudes are described as the reflection of individual characteristics (Achterberg at al., 2017; Gauchat, 2012) or worldviews, which are shaped by lived experiences and socialization (Gauchat, 2011) and differ according to personal characteristics as gender, age, ethnicity, level of education. Hornsey (2020) has visualized this relationship through a science attitudes tree-metaphor: personal traits and characteristics such as ideologies and identity can be considered as the roots and attitudes represent the branches. Connecting these separate streams of academic literature would imply that personal behavior should be seen as another level in the tree, maybe as leaves or flowers, its most visible although transient features. Indeed, in investigating the relationship between personal characteristics, science attitudes and engagement, the attitudes may represent a mediator in the relationship between socio economic status and engagement with science. Emergent literature on the authority of science suggests a connection between deferring to scientific authority and holding anti-democratic views of decision-making (Howell et al., 2020). Given the centrality of deliberative initiatives in the paradigm of public engagement with science, it is relevant to understand the role of attitudes towards science and governance in predicting engagement with science. The second research sub-question is aimed at this gap:

What is the role of science attitudes in the relationship between socio-demographic characteristics and engagement with science?

Finally, the third and last research question draws on the previous two and shifts the focus of the search for reasons for (dis)engagement from specific portions of the public to the way in which (dis)engagement is conceptualized and measured. The framework around which engagement with science has been imagined and conceptualized, as described in the previous sections about definitions and goals of engagement, revolves around empowering the public to take part in science decision-making and co-creation (Davies & Horst, 2016). This framework has influenced the way engagement has been practiced and researched and the way the public has been understood and its preferences questioned. Democratic deliberation is certainly the core of modern western democratic societies. However, such a definition of the aim and content of engagement has left alternative forms of engagement, and their deliberative potential, under-explored. Moreover, as introduced in the last section on the motives for (dis)engagement, institutionalized activities have been observed to be permeated by social inequalities and alternative forms of engagement seem more popular among marginalized social groups (Jensen & Buckley, 2014; Dawson, 2018; Paleco et al., 2021). For these two reasons, investigating alternatives to established forms of engagement can be informative to better understand the socio-demographic dimension of engagement with science, which, beyond being a matter of attitudes, may be related to the (privileged) way engagement has been measured. This final investigation is guided by the way in which Wacquant and Bourdieu (1992, p. 131) described the influence of external circumstances on individual action by observing that "people are not fools [...] precisely because they have internalized [...] the objective chances they face". The application of this framework has been informed by recent elaborations on alternative, personal and informal forms of engagement (Lezaun et al., 2016; Marres, 2016; Bherer, 2023). In a context in which engagement with science is investigated according to a mainstream definition that seems to exclude certain social groups, exploring alternative forms of engagement is valuable to "activate new collective imaginations on what epistemically, technically, environmentally and materially engaged polity might be" (Lezaun et al,. 2016, p. 213). To signal the shift in perspective, the last research sub-question reads as the first one, but inverted:

How can engagement with science be defined from the public's own perspective?

Thus, this dissertation is an attempt to explore and understand public engagement with science from the point of view of the members of the public. I aim to do so while acknowledging individuals' social identities, the constraints and opportunities offered them by modern knowledge societies and the implications this has for science development.

Chapter 3
Methodology

The previous chapter presented the conceptual framework underlying this dissertation and the three specific sub-questions that seek to understand the relationship between individuals' social and cultural status and engagement with science. In this chapter, I will outline the data and analytical strategies employed to answer them. These include both quantitative and qualitative approaches. I start by providing an overall description of the research approach, displayed in Table 2, and thereafter describe and motivate the research design of each empirical study and their limitations.

3.1 A mixed approach to reality

Throughout this study, I seek to understand the role that socio-demographic characteristics have for public engagement with science, and I do so by exploring engagement across different groups of the public, and how it is perceived through the eyes of the public. To address the main research question comprehensively, I utilize both quantitative and qualitative methods. The first two empirical studies included in this project, articles A and B, are based on secondary survey data, while the last one, article C, draws on qualitative interviews conducted as part of this study. Thus, although the structure of the project and the data collection are sequential (Almeida, 2018), this does not qualify as a traditional form of mixed methods study (e.g. Leech & Onwuegbuzie, 2009; Almeida, 2018). Nevertheless, the results of these studies complement each other to provide a comprehensive understanding of public engagement with science both independently and as a whole. The quantitative analysis of survey data contributes to describing the public through their engagement with science and provides insights into corresponding patterns and trends through established categories and measurements. Based on these results, the qualitative analysis of the interviews has been developed to uncover novel ways of understanding and experiencing engagement from the point of view of the public. Moreover, it complements quantitative results by highlighting the underlying reasons for observed patterns and forms the basis for a critical assessment of such measurements.

The ontological approach that is most suitable to studies drawing on contrasting research traditions, such as between (neo)positivism and interpretivism, is the ontological middle ground of critical realism, which is where I place myself. Since its introduction by Bhaskar in the 1970s (Bhaskar, 1975), critical realism has been defined and conceptualized in various ways. Clarke and Braun (2017) give a comprehensive review, highlighting its characteristics that combine features from ontological realism and epistemological relativism. Indeed, according to the critical realist perspective, reality exists independently of the researcher, but it is always mediated by language and culture and thus, impossible to finally access. Applying this perspective to the study of public engagement with science has allowed me to measure levels of engagement while observing the lived experiences and perceptions of individuals within such realities.

When it comes to analyzing and interpreting empirical data, a critical realist approach translates into the need to acknowledge the mediated and situated nature of the data provided by respondents or participants, but also of the researcher's positionality in interpreting such empirical material (Clarke & Braun, 2017). In the never-ending task of scouting for reality, I aim to reach at the underlying mechanisms behind the evidence, recognizing the influence that social structures have on the observable results, while critically evaluating alternative explanations. In the context of this study, this translates into a reflexive and recursive approach to the analysis and interpretation of the empirical evidence, with which I have attempted to comply in the next chapters. Guided in the reflexive approach by Clarke and Braun (2017) and in the practicality of implementation by Lareau (2021), I have tried to build a critical realist account of public engagement with science. The last chapter of this dissertation includes the end result of this approach to reality, as implications stemming from each data source complement and challenge each other, converging to provide an integrated understanding of reality.

3.2 Overview of the research approach

As mentioned above, this dissertation is composed of three empirical studies that use both secondary and primary data, employing quantitative and qualitative approaches. Table 2 includes an overview of the core research questions, along with details on the data and methods used to address them. Overall, I aimed at understanding engagement with science from the point of view of the public and the role that belonging to different social groups has in the relationship with science. To begin, I used established measures and definitions of engagement from the Eurobarometer 516 (2021) described below. I employed this dataset in article A to elaborate a typology of citizens based on their engagement. From these results, I derived hypotheses on the relationship between socio-economic status and engagement with science that I tested using the same dataset in article B. The insights from this second study generated additional questions that could not be answered with quantitative data alone.

Thus, for article C, I conducted interviews to gain a deeper understanding of public perceptions and experiences of engagement with science.

While the approaches employed in this dissertation belong to different research traditions, I believe they concur in building a more comprehensive description of the way in which members of the public understand and engage with science. The results of each study informed the development of the subsequent study. The initial typology of engagement with science contributed to the refinement of the mechanisms investigated in the second study, and both influenced the perspective shift in the last article, which focuses on individual experiences and perceptions to understand engagement. Beyond being linked temporally and logically, the three studies also inform each other through their findings. A discussion of the findings and their connection is included in chapter 5, while the remainder of this chapter introduces the data and research methods used in the three empirical articles.

Table 2. Overview of the research questions and the approaches employed to address them

Research question	Description	Method
How can citizens be defined according to their engagement with science? Article A	To describe forms of public engagement with science according to the standard definition of engagement, I employ data from the Eurobarometer 516 (2021) across 37 countries (n=37097)	Exploratory quantitative study based on secondary data. Principal Component Analysis and Cluster Analysis.
What is the role of science attitudes in the relationship between individuals' socio demographic characteristics and engagement with science? Article B	To test if science attitudes mediate the relationship between socio-economic status and engagement, I test hypotheses developed from the first study on the same dataset.	Quantitative study of testing hypotheses based on secondary data. Structural Equation Modelling.
How can engagement with science be defined from the public's own perspective? Article C	To deepen understanding of how the public engages with science, I conduct 25 interviews with members of the public in England.	Exploratory qualitative study based on primary data. Thematic analysis of in-depth semi structured interviews.

3.3 Exploring established forms of engagement with science

In the first two articles, I employ data from the latest Eurobarometer 516 (2021) on *European citizens' knowledge and attitudes towards science and technology*. The questionnaire was fielded between April and May 2021 through face-to-face and online interviews and the complete dataset was released in September 2021. The final dataset consists of 37,097 respondents aged 15 years or older, across 37 countries (27 EU + 10 non-EU countries).

I decided to use this existing dataset and not to collect my own data for several reasons. The size of the dataset for number of countries and respondents included delivers a professionally documented and representative sample that would have been impossible to achieve with my own efforts. The Eurobarometer constitutes a tradition of a long line of surveys and for many of the items, it includes trend comparisons with previous surveys. Even if this dissertation does not focus on trends over time, the empirical chapters build on and are informed by previous research on engagement with science that used earlier versions of the same measures (e.g. Mejlgaard & Stares, 2010; 2013). Together with these aspects, the way public engagement is measured in this Eurobarometer might be the main advantage of employing this dataset. Public engagement with science is measured by asking the respondents to indicate the frequency with which they perform 12 different science related activities, displayed in Table 3 in order of appearance in the questionnaire. The answer options for each item are: regularly, occasionally, hardly ever, and never. These items investigate the relationship between science and the public through an extensive and representative set of interaction possibilities, according to the corresponding literature. Indeed, as shown in Table 3, these items represent three main forms of engagement with science. The first four stand for a culture-enhancing form of engagement aimed at getting to know science by acquiring information. This taps into understandings of engagement that refer to the *deficit model* or are related to entertainment (Gregory & Lock, 2008; Schwan et al., 2014). The second four describe involvement with science governance, a form of engagement aimed at influencing science policy and decision making. This represents the deliberative aims of engagement with science (Macq et al., 2020). These two groups of engagement activities have been present in a smaller formation in earlier versions of the Eurobarometer (Gaskell et al., 2006) and, as mentioned above, have been used to describe the public according to their engagement preferences and practices (Mejlgaard & Stares, 2010; 2013). The last four items have been introduced in this latest version of the dataset and represent examples of the direct involvement of the public in the process of science co-creation. These items are aimed at capturing the relatively recent trend of public participation in science production and activities of citizen science (Macq et al., 2020). The introduction of forms of co-creative engagement represents an important element of novelty as it allows the observation of their interaction with the other established forms of engagement, which had been missing in previous versions (Schrögel & Kolleck, 2019).

Table 3. Items used to measure public engagement with science in Eurobarometer 516

Culture Enhancement	• Talk about science and technology-related issues with family or friends • Watch documentaries, or read science and technology-related publications, magazines or books • Visit science and technology museums • Study science and technology-related issues in your free time, for instance in a face-to-face or online course
Science Governance	• Sign petitions or join demonstrations on science and technology matters such as nuclear power, biotechnology, the environment or climate change • Attend public meetings or debates about science and technology • Take part in the activities of a non-governmental organization dealing with science and technology related issues • Contact public authorities or political leaders about science and technology-related issues
Science Co-Creation	• Provide personal data for scientific research • Take part in clinical trials • Lend your computer's processing power to contribute to research on complex scientific questions • Actively take part in scientific projects by developing research questions, collecting data, discussing the findings with others, etc.

Thus, the measurement of public engagement is the main point of strength of using the Eurobarometer 516. However, considering it in retrospect, it also represents a limitation. As said, the elements included in Table 3 represent a comprehensive set of engagement activities, however they are all rather formalized and adhering to a mainstream understanding of engagement with science. Except for talking about science with family and friends, all the activities imply interaction between members of the public and a form of scientific institution or formal science outlet. Moreover, most of the items describe a rather active, time consuming and committed engagement with science and technology, setting a distinctively high threshold for its definition. Alternative forms of engagement that regard the personal sphere and the everyday lifestyle (e.g. Lezaun et al, 2016), or more informal activities that take place online or on social media (e.g. Kaskazi & Kitzie, 2023) are not considered. Thus, this represents a specific formulation of public engagement with science which is reflected in the results of the quantitative analyses, especially article A, and is questioned in the qualitative study, article C.

3.3.1 Operationalization of the main variables

Public Engagement with Science

Article A and B are both based on the 12 engagement items presented in Table 3. To operationalize public engagement with science, I decided to perform Principal Component Analysis (PCA) on these items. Alternatively, I could have created three different additive scales according to the theoretical division among the items introduced in the previous section. I decided against this option for two main reasons. The first concerns the exploratory approach that I have decided to apply to this study. Indeed, here the aim was to understand the public based on their own reported engagement habits. Applying a theoretical division among the engagement items would contradict this objective, as it would impose an a priori structure on the respondent's data, potentially deviating from their actual behavioral preferences. This relates to the second reason, which concerns the correlations among the twelve items. As indicated in the correlation matrix included in the supplementary material of article A, the three theoretical forms of engagement are not reflected in the reality of the survey data. Only the culture enhancing kind of activities exhibit distinctively higher correlations, hinting towards the result of the PCA.

Among the possible data reduction methods, I chose PCA as, while retaining most of the variability in the original variables, it provides a smaller set of uncorrelated components (Jolliffe, 2005), which are needed for subsequent analyses (further details in article A). The resulting engagement dimensions are employed in article A to elaborate a typology of engagement and in article B to investigate the role of science attitudes in the relationship between socioeconomic status and engagement. Performing PCA on these items generates 2 components which, indeed, do not follow the theoretical division illustrated in Table 3. The first component describes a *general engagement* with science as none of the items stands out in its characterization. This might be an artifact of the data reducing method employed, but it also signals the conceptual overlap among these activities from the point of view of the respondents. The lack of distinction between activities of science governance and co-creation in defining performed engagement with science might be due to the recent introduction of the latter activities among the wider public, or to the lack of distinction between the publics performing these two kinds of activities. Article A further elaborates on this aspect. The second component describes an *informative engagement* form as it is mostly characterized by the culture-enhancing items in Table 3. In this type of engagement, defined by an inward flow of information, science and technology are serving individuals by providing information and entertainment.

These two dimensions are employed in article A to develop a typology of public engagement with science though Cluster Analysis. This is a data visualization method that produces groups of similar data points – individuals – based on pairwise similarities (Aldenderfer & Blashfield, 1984). It consists of an algorithm which iteratively identifies the two most similar data points and merges them into a new cluster until all individuals belong to a single cluster. The ideal number of clusters that better represent the structure of the data is established afterwards through visual inspection of the resulting structure produced (the dendogram, included in the supplementary material to article A). The typology produced by this method is subject to adjustments in the criteria chosen to set the algorithm, which may influence the structure of the final results (Aldenderfer & Blashfield, 1984). Nevertheless, I chose this method as, compared to alternative ways of elaborating typologies such as Latent Class Analysis (Füchslin, 2019), because it allows more awareness of the data structure and clustering process, which aligns with the exploratory approach of the study.

Socio-economic status

Article B investigates the role of science attitudes in mediating the relationship between individual socio-demographic characteristics and engagement with science. In particular, the socio-demographic characteristics investigated refer to the concept of Socio-Economic Status (SES), which is related to the concept of social class discussed in chapter 2. To capture the multidimensionality implied in socio-economic status, I chose to measure it through one comprehensive additive scale composed of: individual educational level, parents' educational level, job prestige, and self-assessed social level. Income does not figure among the elements as it is not included in the Eurobarometer, a limitation that is discussed below. This way of measuring socio-economic status is unconventional, but motivated partially by the results of article A, and partially by the intent of capturing the effect of the heterogeneous set of experiences with which individuals live their daily life. SES has been measured in previous literature in various other ways. Single items such as objective and subjective indicators of cultural and economic capital are often used according to specific research interests (Diemer et al., 2013). Composite scales are more often criticized for leading to unclear interpretation of the results (Oakes &

Rossi, 2003). However, since I cannot hypothesize on the specific effects of each element composing social status, I decided to build a scale of items capturing objective and subjective measures of economic and cultural status and background. Further elaboration on the details of the scale and its use in the analysis is included in article B and relative supplementary material.

This dimension is employed in article B to investigate its direct relationship with engagement with science and indirect though science attitudes. This analysis is performed through Structural Equation Modelling (SEM). SEM refers to the simultaneous estimation of multiple regressions to test a relationship between variables while accounting for latent variables (Silva et al., 2019). In other words, it allows the incorporation of Confirmatory Factor Analysis (CFA) into the estimation of a path model. Thus, I choose to employ SEM for the possibility to test an intricate structure of relationships among variables in a single model, while employing latent variables as measurement error-free constructs. Public engagement with science is the latent variable in question, whose operationalization yields a comparable result to the dimensions identified in article A. Details on model specification are included in article B and relative supplementary material.

3.3.2 Challenges of using secondary data

Despite the number of advantages it provides, this dataset also presents challenges. The measurement of some important variables in this study, especially for article B, is imperfect. The individual level of education is only measured by asking respondents to indicate their age at the end of full-time education and not the highest level of education achieved (as in other social science surveys such as the European Social Survey). This measure is certainly useful for specific purposes such as comparing the educational achievements of age cohorts across time and space. It also allows a quicker data production and release as the provision of a cross-countries harmonization is not needed, as is often the case with education data (Ortmanns & Schneider, 2016). However, it also provides incomplete information as the start age and duration of educational systems is not standardized between or within countries, and a later end age does not always imply a higher educational level. This adversely affects the precision of this measure as used in article B. A similar conclusion can be drawn for the measures regarding respondents' economic situation and employment status. A standardized objective measure of household income is not included, but this is only measured through self-assessed social level and reported difficulties in paying bills, which limits the scope of the possible analyses. Employment status is also not measured according to standard classifications (e.g. ISCO codes), which makes the translation into job prestige scales (e.g. EGP in article B) imperfect. More details on the treatment of these variables can be found in section 3.2 of article B. Finally, it must be mentioned that the general approach of Eurobarometer surveys has been critiqued for describing a partial reality, representing the European Commission's goals (Law, 2009; Nissen, 2012). This observation reinforces the relevance of investigating public engagement with science from various viewpoints and through different data sources.

Finally, the Eurobarometer is a multi-country survey which allows for comparison across countries. However, observing the differences in engagement across countries is not one of the focus points of this dissertation and neither of the two studies employing this data investigates differences across local specificities. In article A, the results of the cluster analysis are comparable to previous studies elaborating typologies of European citizens based on their engagement with science which observed the adaptability of the constructs across European countries (Gaskell et al., 2006; Mejlgaard & Stares, 2010; 2013). However, further elaborating on the country-level characteristics of engagement with science was beyond the scope of the study. Moreover, the same analysis has been repeated in another study on a subsample of the Eurobarometer data without highlighting significant variations in the informative potential of the typology (Starkbaum et al., 2023). In article B, the analysis variation at the country-level is controlled for through fixed-effect models, thus the results can be interpreted as general trends at the European level. The computational possibilities of Multilevel Structural Equation Models in RStudio are still limited and a multigroup analysis is troublesome across 37 countries. Details on this choice and the measures taken can be found in article B. Thus, disregarding local variation in the first part of this dissertation is not motivated by the fact that local contexts and the relationship of individual characteristics with the culture of science do not interact. Previous studies observed how these often do covary, although for the variety of confounding factors that constitute contextual variation, they struggled in offering comprehensive interpretations (Bauer et al., 2012; Makarovs & Achterberg, 2017; 2018). Indeed, considering local variation and interpreting it meaningfully necessitates deep contextual knowledge and careful consideration which, even if informative, is not part of the main goals of this dissertation.

3.4 Understanding alternative engagement with science

Data from the Eurobarometer limits the possibilities of exploring public engagement with science to the set of items through which it is measured in the survey. Two options to further explore engagement are an additional survey experiment and an interview study. The former aligns better with the neo-positivist tradition in which the Eurobarometer locates, although it implies a series of assumptions and decisions that would not align with the last research question I developed. Survey experiments are useful tools for understanding human behavior in a controlled setting while testing specific hypotheses (Treischl & Wolbring, 2022). However, the final research question I aimed at answering revolves around understanding the practice of engagement with science from the point of view of the public and not at testing a mechanism. Thus, I decided to complete this dissertation with a qualitative interview study to understand engagement with science through contributions by members of the public, allowing them to freely define and elaborate on it. Investigating behavioral choices, such as forms of engagement with science, through qualitative interviews without any form of ethnographic account is a debated approach. Before moving to describing the specificities of the third study, in the next lines I will briefly delve into this academic discussion.

The core of the debate over the significance of interviews in studying social issues revolves around the concept of *attitudinal fallacy*. Jerolmack and Khan (2014) introduced this concept to emphasize the limitations of reliance on self-reported attitudes when accounting for individual behavior. Indeed, the authors argue that people might not accurately report their thoughts and their stated opinions might not align with their unobserved behaviors. The concept of attitudinal fallacy was soon after challenged by Vaisey (2014), who recalls the vast empirical literature in contrast with Jerolmack and Khan's (2014) contention while highlighting the limitations of any single account of social issues. Citing a notorious example of an informative and non-antagonistic dialogue between diverse methodological traditions (Lareau, 2003 and Cheadle & Amato, 2011), Vaisey introduces the concept of *methodological pluralism*, then taken up with more emphasis by Lamont and Swindler (2014). This idea refers to the application of a vast range of methods when aspiring to a comprehensive understanding of reality. The potential gains of combining diverse methods against (artificial) methodological dogmatism and the crucial role played by interviews in capturing individual experiences with depth and nuance is highlighted by other contributions as well (e.g. Pugh, 2013; Lamont & Swindler, 2014). Interviews are to be intended not only as yet another data collection method, but their value relies on their capacity of data construction and exploration beyond observed behavior (Pugh, 2013). Lamont and Swindler (2014) clearly lay out the advantages and pitfalls of employing interviews and highlight the precious role these have in exploring the significance and the imagined meanings for the informants of the actions investigated. Following these accounts, I've trusted the potential of interviews, among the variety of qualitative methods, to provide meaningful content for the present study of the relationship between social status and public engagement with science, and I believe I have been rewarded.

3.4.1 Conducting the interviews

To select informants for this study, I have followed a purposeful maximum-variation strategy (Patton, 2014:264) in order to capture a large range of perspectives within the research interests of the study. Indeed, selection criteria have been informed by the results of the first two articles, especially article A, and of previous literature on engaged and disengaged citizens (e.g. Dawson, 2018; Paleco et al., 2021). Participants could not be enrolled in a course of study, be employed in high prestige or sciences-intensive jobs (managers, engineers, architects, medical doctors), work as lecturers or researchers for a university or other research institutions nor have immediate family members that do so. These characteristics often describe members of the public from privileged social classes and short distance to science (Većkalov et al., 2022), that have high levels of engagement with science through formal channels, but also science literacy and positive attitudes (see article A). I aimed at reaching individuals who do not comply with these characteristics. Two other strict selection criteria were fluency in spoken English and age over 18. I sought to achieve variety on other demographic characteristics such as age, gender, employment and ethnic background. Of the 25 participants, 6 are males and 19 females, 5 have non-British background and the age range goes from 27 to 75, with an average of 48. Most participants have children (n.19), who were often referred to in their narratives. The most common level of education is secondary education (n.8). Employment profiles are quite different, with the most common being work in the care sector (n.6), but there are also teachers / instructors (n.4) and web developers (n.2). The characteristics of each informant are included in the supplementary material of article C.

I recruited the participants online by posting advertisements on various social media groups, such as Facebook or Reddit, linked to the town (and not directly to science-related topics), offline by hanging the same advertisement in various locations (community centers, cafés, libraries, supermarkets), and by asking participants to distribute among their networks. Interviews took place in cafés or at the public library and were audio-recorded to secure accuracy. Participants information and consent form are included in Appendix A and were provided to the participants digitally beforehand and on paper, to sign before the start of the recordings. Each interview lasted for about 50 minutes on average (the shortest being 34 minutes and the longest 87) and an interview guide directed each session while leaving space for the participants to diverge and freely contribute to the construction of the interview material.

I have built the interview guide based on evidence from existing literature and the results of the first two studies, which also prompted the corresponding research question. Beyond standard opening and closing questions, the guide is divided into four main blocks investigating informants' experiences and perceptions of engagement with science from different angles. In order, the four sections refer to: personal relationship with science, encountering science in daily life, attributing value to engaging with science, and linking science and civic engagement. The complete interview guide is available in the supplementary material to article C. The core questions of each block were asked to each of the participants, but informants were given space to explore unplanned directions and topics. For the study, this has been especially useful in the first interviews to adjust the guide accordingly in terms of interesting topics or challenging questions. For the informants, having the space to elaborate on their contributions and direct conversations seemed to help those who felt uncomfortable to get acquainted with the situation and express themselves more freely. In addition, at the end of each interview, informants were asked to fill in the survey items measuring frequency of engagement with science included in the Eurobarometer 516, the same items displayed in Table 3. For space reasons, the resulting information was not discussed in article C, but it informed the reflections that guided the analysis as analytic memos and notes. Finally, upon completion of the interview each participant was given a 10£ voucher for grocery shopping. The practice of offering monetary compensation to participants in qualitative studies is debated (e.g. Head, 2009). I believe that the time and effort participants invest in supplying researchers with material for the advancement of their work and careers, as well as science, should be recognized as working time and when feasible remunerated as such.

3.4.2 The English context

The interviews, informing Article C, took place in a medium-sized town in England. I chose to undertake this study in an English town for three main reasons. First, I chose the UK for the widespread awareness of social hierarchies among the population which often appeared unprompted during the interviews. This represents an interesting setting for a qualitative study aiming to understand personal perceptions and experiences, traditionally influenced by social conditions. Second, the United Kingdom is not new to research on the relationship between science and the public or to implementation of policies aimed at bridging this gap. This translates into a richer ground of studies regarding various aspects of this relationship on which the present analysis can build, be informed by, and contribute to. Third, the English town chosen is a medium-size town at 1h train ride from London, of around 200.000 inhabitants with average population characteristics resembling those for England as a whole, with lower general income but otherwise comparable qualifications. The town is also home to a university of about 17.000 students, many of whom are international students, divided across a variety of departments: mostly within humanities and social sciences with a minority within the natural sciences and health. The body of students constitutes a large share of the town's population, however most of these reside on campus, which is located in the outskirts of town, and leave the town soon after the end of their studies. Similarly, many of the researchers and lecturers live outside of town. Thus, the existence of this science institution is well recognized, but does not seem to exert its presence extensively in the city. For these reasons, the chosen location represents a suitable setting to carry out research on the public's perceptions and experiences of science and engagement with science. This study has no aspiration of comparison or generalization beyond the context in which it takes place and the members of the public included in it. Rather the aim is to observe how non-science professionals make sense of science in their daily life and the instances in which they recognize it, in a context of moderate presence of a scientific institution.

3.4.3 Operationalization of science in the interviews

Deciding whether to focus the interviews on a specific conceptualization of science, whether a topic, a field, or specific technology, or to leave it open to the informants' interpretation was not an immediate decision. Advantages and challenges can be found for either choice. Indeed, focusing the interviews on a specificity of science may make it easier for the respondents to relate to the concept and to have opinions or formulate reflections. However, at the same time it might also drive away those among the public who are not familiar with the concept investigated or for whom the concept is for some reason controversial. At the same time, discussing science in general might be confusing and too broad to discuss or might deter those among the public who do not think of themselves as being close enough to the general concept of science. Nevertheless, the general concept of science is less likely to be interpreted in a controversial way and can be adapted based on what each informant interprets science to be. Especially for this latter reason, I decided not to delimit science myself, but to let the participants of the study describe their interpretation of science in the beginning of the interview. When inquiring about specific forms of engagement with science, I framed science as "science and technology", which is an element of continuity with the formulation of science adopted in the Eurobarometer. The interview guide is included in the supplementary material of article C.

To elicit definitions and ideas of science, the first question that was asked to all informants was to provide the first three words or mental associations coming to their mind if I asked them to think about science. Answers to this question can be roughly divided into three main groups. The first and the most frequently mentioned is composed of school references. These references are either regarding science subjects, with biology, physics, and chemistry the most mentioned, or other elements of the school years, such as Bunsen burners, laboratories, planets, atoms, equations, or learning. The second group in order of frequency includes words relative to technical and natural or medical sciences, as computers, robots and technology, or insects, germs, vaccines. The third group is composed of words describing elements of science, such as observation, facts and context, or abstract words describing science, such as world changing, clever, and complicated. Interesting is to notice that these are generally positive. Problematic aspects of science are cited more often when it comes to technology and are never attributed to the science process itself. Thus, informants' mental associations regarding science seem to be related to their school years, most often include natural and technical sciences, and have a positive connotation (except for mentions of lack of understanding). References to social sciences rarely appeared spontaneously. Finally, it must be noticed that these spontaneous and contextual mental associations did not define the understanding of science during the interviews, but only served to set the scene and start a conversation. Indeed, as one of the respondents remarked "When you just asked that question, I was thinking ..well, what do I think about?.. And then I literally thought chemistry from school. But that's not something I normally do" (Sylvia, 46, Homemaker).

3.4.4 Coding strategy

After data collection, the audio-recordings were transcribed verbatim using NVivo Transcription, which is an online automated transcription service. A research assistant helped me with the production of part of the transcripts, which I then revised. Based on these transcripts, the analysis of the data took place using the NVivo software and followed a two-step approach (Miles et al., 2018; Saldaña, 2021) although it has been in fact a recursive process (Clarke & Braun, 2021; Lareau, 2021). The first step is the creation of first order codes. These are detailed open codes created mostly inductively to identify salient text and relevant themes mentioned by the interviewees. Respondents' contributions were guided and affected by the structure of the interview guide, and thus by the theory on which it builds, but the main goal of this first round of coding was to identify cross-cutting themes that could then be interrogated to answer the research questions. The openness of this initial coding cycle allows the complete exploration of the information included in the interviews keeping the analysis open to unexpected connections that would not be possible to observe by applying a pre-defined structure to the data. In this phase, various types of codes were used, such as descriptive codes, emotional or values codes, in addition to attribute codes (Saldaña, 2021). Often multiple codes were assigned to the same string of text. A more deductive structuring of the codes took place in the second step. This is the categorization of the initial open codes into broader themes describing emerging patterns, themes or focuses (Saldaña, 2021). These codes are reflective of the themes mentioned by the participants but are also guided by previous research and the theoretical interests that guided the formulation of the research questions. Article C does not include everything that was mentioned by the informants but only focuses on what is relevant in the context of this study.

3.4.5 Challenges of interview data

I believe that employing both quantitative and qualitative methods and analyzing a diverse range of data has contributed to building an interesting and informative study, however not without challenges. I have already discussed the limitations and the challenges presented by the Eurobarometer, so I limit this discussion to the problematic aspects presented by the interviews.

A significant one is related to the role of the interviewer, as recurrent in qualitative studies (Limerick et al., 1996; Lamont & Swindler, 2014). In this case the interviewer, me, was a representative of science with the task of interviewing members of the public about their perceptions and experiences related to science. The fact that I would be the interviewer and that I am employed in a university working on a research project was made clear to all participants upon recruitment and was repeated at the beginning of each interview. In the few introductory words, I also mentioned to the informants the exploratory aim of the study in which I was not aiming at proving a point or promoting science – nor the opposite. With this introduction, some efforts in delivering an informal tone and the informal locations for the interviews (cafés), I aimed at mitigating the power imbalance between myself and the informants. This was certainly only partially successful. Although I think that the honesty and accuracy of the information provided was not affected by this relationship, several participants were at first in discomfort in expressing their thoughts and relaxed over the course of the interview. This might be due to the relationship that was developed during the hour-long interviews (discussed in Limerick et al., 1996), but the structure of the interview might also be a factor. Indeed, while the second part focuses on opinions on external subjects such as engagement with science and the role of science in society, the first questions are aimed at understanding the respondents themselves and their personal relationship with science. When discussing these topics, informants referred to their school days which were often related to a sense of inferiority and incompetence. Mitigating these outcomes is a difficult task when it comes to a sensitive topic, which personal experiences with science might be. A strategy might be to provide the informants with the general topics of the interview beforehand, for them not to be surprised during the discussion. This might hinder the spontaneity of the answers, although prompting immediate and spontaneous thoughts about science produces on-the-spot replies that might also not reflect individuals' real thoughts.

A second aspect that should be mentioned is the limited variety of people that were successfully recruited for the study. Especially for what concerns gender, age, and attitudes towards science, as most of the informants are women, middle aged and interested in or positively disposed towards science. Upon reflection, I could put forward some reasons that might have generated this outcome. The topic of the study itself might be mostly attractive to those who have an interest in science; my positionality as a female researcher might generate more willingness to help among women; the grocery voucher as a reward might be attractive to members of the public mostly concerned with household tasks; the mode of recruitment, mostly through Facebook groups or fliers in cafés, might be less attractive to a younger population. Modifying some of these elements might result in a more demographically varied group of participants, which may be conducive to different conclusions, although these do not represent key dimensions of the analysis.

Finally, sustaining the duration of the interviews emerged as a challenge. Indeed, a one-hour engaged, and reflexive conversation seemed to be (more) taxing for those individuals unaccustomed to embarking in demanding discussions on a regular basis. This observation is coupled with the fact that the interview guide appeared not accurately tailored to members of the public that were not used to discussing the social implications of science in their daily lives (most people). As an example, question 9 includes a ranking exercise among three forms of engagement with science: being up to date with science and technology developments, making one's voice heard in relative government decision making and participating in activities of science co-creation. Answering such a question would be demanding for academics as well, and indeed informants struggled in making sense of the request and keeping in mind the items while elaborating a coherent answer. To manage this difficulty, I printed the three options on three pieces of paper of different colors which could be moved around. At times I have also changed the request from ranking to just discussing each item. This was my first qualitative project, and each stage has been a learning experience. It is no stretch to say that through it I became a better researcher and more aware human being.

In the previous chapters I have outlined the main focus of the dissertation, the core concepts that guided the development of the project and the overall research approach. The following three chapters include the empirical part of the dissertation, in the form of three articles. These results are discussed in the last section of this dissertation, chapter 7.

Chapter 4
Article A

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Who engages with science, and how? An empirical typology of Europeans' science engagement

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Abstract

This article seeks to expand the literature on science attitudes by developing an empirical typology of people's engagement choices and investigating their sociodemographic characteristics. Public engagement with science is gaining a central role in current studies of science communication, as it implies a bidirectional flow of information, which makes science inclusion and knowledge co-production realizable goals. However, research has produced few empirical explorations of the public's participation in science, especially considering its sociodemographic characteristics. By means of segmentation analysis using Eurobarometer 2021 data, I observe that Europeans' science participation can be distinguished into four types, *disengaged*, the largest group, *aware, invested*, and *proactive*. As expected, descriptive analysis of the sociocultural characteristics of each group suggests that disengagement is most common among people with lower social status. In addition, in contrast to the expectations from existing literature, no behavioral distinction emerges between citizen science and other engagement initiatives.

Keywords

citizen science, cluster analysis, public engagement, science publics, stratification

1. Introduction

Research on the social embeddedness of science has made a significant contribution to the science and technology literature, and recently, emphasis has been on analyzing various aspects of public participation in science (Delicado, 2021). Its applications have been studied as inputs to processes of democracy and science, such as policy-making practices (Jasanoff, 2003), participatory decision-making and consensus building (Bento and Brás, 2021), knowledge co-production (Callon, 1999), or citizen science (Irwin, 1995). Public engagement with science imposes a shift of perspective in how the relationship between science and the public is envisioned and, thus, in the roles ascribed to each (Cerroni and Simonella, 2014). Both actors become sources and recipients in the exchange, and this is crucial in achieving goals such as democratically empowering citizens,

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improving public access to scientific knowledge, promoting public acceptance of science, or enhancing scientific innovation and scientific study curricula (Weingart et al., 2021).

Given this potential, science engagement has become a central concept in public understanding of scientific research and a relevant tool in policy-making. Nevertheless, the spread of its use has gone along with the fragmentation of its meaning, which is mirrored in a variety of standpoints on its fundamental mechanisms, components, and goals. Engagement appears in related studies as an umbrella term, contextually defined according to the single study's content, in terms of objectives, role of the public, or types of activities (Weingart et al., 2021). There can be several forms of engagement and differences in how and to what extent citizens engage with science. To understand and enhance public engagement with science, it is thus important to identify different audiences and groups with respect to engagement (Füchslin, 2019).

Typologies of engagement exist but represent theoretical frameworks on which to map existing engagement activities. What appears to be missing is an empirical exploration and discussion of these efforts against the concrete engagement practices of the general population. The available empirical studies aiming at creating typologies of science publics have been developed around indicators of science perception (Cámara et al., 2018), attitudes (Pullman et al., 2019), or literacy (Kawamoto et al., 2013), and are thus focused on specific determinants of engagement instead of engagement practices themselves.

Among forms of engagement, the literature distinguishes between activities of knowledge acquisition or building, where citizens engage with science culture, attend lectures, or visit museums, and activities aimed at influencing policy making, where they join demonstrations or attend public meetings related to science and technology (Macq et al., 2020; Mejlgaard and Stares, 2013). A distinct part of the literature on science engagement consists of research on citizen science, a modality of engagement focused on the "public's collaboration in research" (Delicado, 2021). Citizen science can both be seen as a higher degree of engagement to influence the direction of science or as interest-driven participation in knowledge-building (Strasser et al., 2019). Hence, it is unclear how citizen science is linked to other forms of engagement. Research has investigated various related aspects, such as people's motivation (Domroese and Johnson, 2017) or attitude change (Dean et al., 2018; Yanco et al., 2021), but the relationship between this practice and other engagement initiatives is yet to be observed.

In all, connection with the reality of people's practice is necessary to inform discussions about the role of science in society, to develop appropriate tools for engagement that are based on actual public perception as opposed to stylized models. Thus, the present study aims at developing an empirical typology of science engagement based on practices enacted by the public.

Employing data from the Special Eurobarometer 516 (2021) on public knowledge and attitudes toward science and technology, this study attempts to explore citizens' (reported) science engagement. I use principal component analysis (PCA) to identify meaningful linkages among different engagement activities, which I thereafter use to group the respondents according to their modes of engagement through cluster analysis. Finally, I describe the resulting clusters according to selected demographic and attitudinal characteristics. By doing so, it is possible to gain knowledge on how the public interprets the role of science, how they engage with it, and if the engagement practices are unique to any social or attitudinal group. The items included in this dataset compose the richest battery of science engagement possibilities employed to date in Eurobarometer surveys, allowing production of a new comprehensive analysis of engagement for what concerns the scope of the activities considered.

2. Background

Among the various attempts to create theoretical mappings of public engagement with science, the core is represented by the studies of Arnstein (1969), Rowe and Frewer (2005), and Bucchi and

Neresini (2007). Arnstein (1969) developed a classification of public participation in decision-making around the concept of citizens' power. This is an important contribution setting the focus on what engagement means for the engaged, fundamental for a rich reflection on the goals of the activities and the role of the participants in the opening up (Stirling, 2008) of democratic institutions. More recently, Rowe and Frewer (2005) attempted to classify public participation initiatives by reflecting on the underlying mechanisms and the structural characteristics defining them. In their study, the authors focused on the nature and the flow of information between the actors involved, taking the concept of effectiveness as an important evaluative tool for public engagement. Finally, Bucchi and Neresini (2007) aimed with their contribution to expand the definition of public engagement from only including top-down activities, reminiscent of the deficit model, toward including also spontaneous realizations of public initiative.

Categorizations as those mentioned above embody important efforts to reflect on the relevance of public engagement with science and its defining features. However, these contributions are mainly concerned with classifying existing participation initiatives and do not contribute with insights from the actors and their participation preferences. Furthermore, it has been observed that research often views categories as within a linear hierarchy, which "hinders a holistic consideration of all forms of dialogues and participation as different manifestations of participation in science" (Schrögel and Kolleck, 2019: 85). Targeting these shortages, in a more recent attempt to define public engagement with science, Schrögel and Kolleck (2019) elaborated the "participatory science cube," a descriptive theoretical framework more adaptable to the diversity of participation approaches. The three-dimensional framework takes into consideration the degree of public involvement in decision-making and of nonscientists' inclusion in the process of knowledge generation to create an evaluation of the engagement activities which does not implicitly rank them.

Typologies of citizen science initiatives vary between normative and practical considerations, including the role of citizens in the process of knowledge production (Wiggins and Crowston, 2011) or classifications of project implementations (Bonney et al., 2009). As an example, Bonney et al. (2016), in a wider spectrum study on the outcomes of citizen science projects, revise a previously elaborated typology of these activities on the basis of their nature and structure. These classifications are useful to map citizen science activities by reflecting on the expectable outcomes and the measures needed to achieve them, but it is to be noted that a model integrating this approach with other public engagement measures is still missing (Schrögel and Kolleck, 2019).

Other empirical studies include a growing number of attempts to segment science audiences. These classifications focus mainly on a variety of attitudes toward science (for an overview: Füchslin, 2019), while behavioral typologies focusing on science engagement seem to be underrepresented. In two studies, Mejlgaard and Stares (2010, 2013) analyze measures of engagement along with other science attitudes, respectively, competence and preferred participation. The former study focuses on exploring the concept of scientific citizenship, whereas the second expands the idea of democratic deficit. These studies contributed to the understanding of the relationship between science engagement and other science attitudes, though do not focus on developing the concept of science engagement alone. The present article aims at providing further understanding of the public's engagement patterns using a much wider set of participation activities than in previous studies. This allows a better grasp of the concept of public engagement with science, which I argue is yet to be completely understood.

Typologies and segmentation analyses are useful instruments as their development requires and offers reflections on the relevant aspects to underline and investigate the topics considered, sometimes even more relevant than the categorizations produced. As Rowe and Frewer (2005) put it, "the typology itself should be seen as of secondary importance to the explication of the rationale for its necessary development and the process of producing it" (p. 285). Without reaching this extreme, I argue that in the field of public engagement with science, a typology can still find its place as it promotes a compelling reflection about what is considered relevant for the development of engagement instruments (Wynne, 2007), but also about the ways in which people make use of these possibilities in real life. The present study contributes to this literature as an attempt to describe people's relationship with science based on their engagement choices and to observe how other sociodemographic attributes characterize types of participation. Building on the discussion above, this study develops in three stages corresponding to the following research questions:

RQ1: Which theoretical distinctions between science engagement activities can be identified based on people's science engagement activities?

RQ2: How can science public be defined according to the ways in which people engage with science and technology?

RQ3: How do different modes of science engagement differ in their demographic characteristics and attitudinal preferences?

3. Data and measures

Data

I analyze data from the Special Eurobarometer 516 focusing on "*European citizens' knowledge and attitudes towards science and technology*." The questionnaire was fielded between April and May 2021 through face-to-face interviews, and the complete dataset was released in September 2021. The final dataset consists of 37097 respondents aged 15 years old or over, across 37 countries (27 EU countries + 10). The main interest of the analysis below is a battery of 12 items corresponding to various science engagement options, further explained in Measures. I handled missing/invalid observations through list-wise deletion, which led to a final sample of 35913 units.

Methods

There is no commonly agreed method to undertake segmentation analysis in the literature, and the existing studies follow two main method families: cluster analysis, with or without previous data reduction (PCA/factor analysis), and latent class analysis (Füchslin, 2019). I opted for a two-stage analysis following the first method. First, I performed a PCA to identify uncorrelated components underlying the 12 engagement items, and then I employed these components in a cluster analysis to classify respondents according to their corresponding scores. These groups have then been characterized according to differences and communalities in the distribution of demographic variables and other attitudinal variables related to participation. The 12 items that were employed in the analysis are composed of ordinal scales, thus following the literature on cluster analysis with ordinal variables (Han et al., 2011; Walesiak and Dudek, 2010), I decided to compute a hierarchical agglomerative cluster analysis, applying Euclidean distance as dissimilarity measure and Ward's linkage algorithm[1] (Aldenderfer and Blashfield, 1984; Hair et al., 2010; Runge et al., 2018). The analysis has been performed using the software R (version 4.1.1) and the functions *princomp* for PCA (built-in R function) and *hclust* for clustering (package fastcluster, version 1.2.3).

Measures

Engagement with science is investigated in the questionnaire by a set of items asking the respondents to indicate the frequency with which they perform various (12) science engagement activities

Table 1. Descriptive statistics of the 12 items considered in the subsequent analysis.

Item	*M*	*SD*	Median
Culture enhancing			
Talk about science and technology-related issues with family or friends	1.55	1.00	2
Watch documentaries, or read science and technology-related publications, magazines, or books	1.68	1.02	2
Visit science and technology museums	1.07	0.93	1
Study science and technology-related issues in your free time, for instance in a face-to-face or online course	0.81	0.94	1
Governance oriented			
Sign petitions or join demonstrations on science and technology matters such as nuclear power, biotechnology, the environment, or climate change	0.73	0.92	0
Attend public meetings or debates about science and technology	0.57	0.81	0
Take part in the activities of a nongovernmental organization dealing with science and technology-related issues	0.47	0.78	0
Contact public authorities or political leaders about science and technology-related issues	0.41	0.73	0
Co-creative			
Provide personal data for scientific research	0.85	0.97	0
Actively take part in scientific projects by developing research questions, collecting data, discussing the findings with others, etc.	0.53	0.85	0
Take part in clinical trials	0.50	0.82	0
Lend your computer's processing power to contribute to research on complex scientific questions	0.37	0.73	0

$N = 35.913$, Min = 0, Max = 3.

(battery Q14). These items are ordinal variables of five categories each, corresponding to: 1 = "*Yes, regularly*," 2 = "*Yes, occasionally*," 3 = "*Hardly ever*," 4 = "*No, never*," and 5 = "*Don't know*." The latter has been set as invalid and excluded from the analysis. The remaining scale was reversed and recoded for a more meaningful interpretation, obtaining 12 variables going from 0 = "*No, never*" to 3 = "*Yes, regularly*." See the full label of the engagement items and descriptive statistics in Table 1. These items have been developed by field experts with the specific aim of investigating the relationship between science and the public as a representative set of interaction possibilities. Moreover, these items have been elaborated as indicators of three possible forms of public engagement with science, in accordance with the corresponding literature. The first four describe science participation aimed at getting to know science, an information-oriented type of participation; the second four represent involvement as active users, aimed at influencing science policy and decision-making; whereas the last four are examples of direct involvement in the process of science, in a co-creative form of participation. In the table, the items are displayed according to this theoretical division. Inside each group, the variables are ordered from highest to lowest mean.

From Table 1, it can be noticed that the answers given to the 12 items are not equally distributed. In the first four questions, respondents seem to have used the whole response scale and tend toward high values, whereas for the next eight items, they concentrated in the lower part of the scale. The full distribution of the respondents across items and response options is available in the Supplemental Material. Thus, at a first glance when it comes to science engagement, respondents seem to be more acquainted with culture-enhancing activities over the others.

4. Principal component analysis

Items among the first eight have been used previously to measure science engagement (see Mejlgaard and Stares, 2013), whereas the last four have been newly introduced in this edition of the survey. Thus, given the novelty of the battery, the study goals, and the fact that the subsequent cluster analysis favors the use of not strongly correlated variables (Aldenderfer and Blashfield, 1984; Hair et al., 2010), I decided to perform a PCA on these 12 items. Indeed, PCA is useful to reduce the dimensionality of multivariate datasets, while retaining most of the variability in the original variables with a much smaller set of uncorrelated components (Jolliffe, 2005). This first step of the analysis helps answer the first research question regarding whether the theoretical division among the three types of engagement mentioned above can be found based on people's engagement activities.

Correlation coefficients among the 12 items do not show distinctive patterns but indicate moderate to high (.3–.7) correlations among the items. The full table is available in the Supplemental Material. Therefore, I proceeded with the PCA, which resulted in two principal components. The results of the analysis can be inspected in Table 2. According to the Kaiser rule on extracting the optimal number of components, in this case, only the first two should be retained as they have Eigenvalue higher than 1. Castell's Scree Test, included in the Supplemental Material, indicates the same two-factor solution. These first two components together explain around 65% of the variance. The Kaiser–Meyer–Olkin measure of sample adequacy is .93 for all variables and well above .84 for each variable, thus indicating that the data are suitable for this analysis. The resulting scales have been constructed using the component scores to obtain indicators that are as faithful as possible to the natural structure of the data. Component scores can be defined as standardized weighted averages and are constructed including all the items weighted according to their relevance in each scale (measured with component loadings). Correspondingly, each respondent is assigned a score on each of the two new components, based on their answers to each item comprising the scales.

The resulting components show that the theory-driven division among the activities introduced before cannot be observed when it comes to people's preferences about engagement activities. Still, the two types of engagement highlighted reflect different levels of personal involvement and directionality of the exchange between the actors. The first component seems to stand for an overall engagement, as it is difficult to single out which items mostly characterize it. This is partly due to the fact that PCA tends to maximize the variance explained in the first component, but also underlines the possible conceptual overlap among the activities from the point of view of the respondents. In this first component, activities of personal engagement with science mix with others aiming at affecting decision-making, or focusing on the co-production of science, signaling what I label as *general* engagement. The second component, instead, is clearly defined by items describing culture-enhancing kind of activities, which previous literature has labeled as *horizontal* engagement (Mejlgaard and Stares, 2013). These include talking with friends or family about science-related issues, watching documentaries or reading science-related publications, and visiting science and technology museums. These are all activities carried out spontaneously by the individuals, in an inward flow of information, and seem oriented toward knowledge acquisition and formation of scientific thinking. In this type of engagement, science is uniquely serving individuals, by providing information, topics of discussion, or entertainment. I label this form of participation as *informative* engagement. Forms of engagement aimed toward science governance or focusing on the co-production of science, establishing a counter flow of information from lay people to authorities managing and making science, do not seem to be definitive of specific types

Table 2. Above: eigenvalues; below: unrotated components loadings ($N = 35913$).

Component	Eigenvalue	Difference	Proportion	Cumulative
1	6.04	4.66	0.50	0.50
2	1.39	0.62	0.12	0.62
3	0.77	0.15	0.06	0.68

Variable	*General*	*Informative*	Unexplained
Talk with friends about science	0.26	**0.51**	0.24
Watch documentaries/read science	0.25	**0.55**	0.20
Visit museums	0.29	**0.31**	0.37
Study science in free time	**0.31**	0.13	0.41
Sign petitions/join demonstrations	0.28	−0.04	0.51
Attend public meetings	**0.32**	−0.13	0.35
Participate in nongovernmental activities	**0.31**	−0.24	0.32
Contact public authorities	**0.30**	−0.29	0.34
Provide personal data for research	0.29	0.02	0.48
Participate in science projects	**0.30**	−0.17	0.41
Take part in clinical trials	0.27	−0.20	0.52
Lend computer to research	0.27	−0.31	0.42

Only the first three components are shown.
Eigenvectors equal or above 0.30 are in bold.

of engagement. In particular, the recently included items referring to activities of citizen science do not seem to be distinguishable from other more proactive items.

5. Cluster analysis

To address the second research question on how to define science publics according to the ways in which people engage with science and technology, I performed a cluster analysis on the outcomes from the PCA. By visually inspecting the dendrogram, available in the Supplemental Material, a four cluster solution seems plausible. The statistical tests used here are multivariate analysis of variance (MANOVA) and Scheffé tests, as the wide sample size prevents the computation of other stopping rules to select cluster solutions. MANOVA results show that the two modes of engagement differ in a statistically significant way among the clusters ($F = 18{,}974$, $p < .001$) and Scheffé multi comparison of means analyses suggest that the differences between the clusters for all the variables are statistically significant.

The distribution of the respondents across the clusters is not even, as the method used does not specifically aim for a homogeneous distribution. Table 3 shows the corresponding means for the 12 items in each of the four clusters which have been labeled accordingly. The first cluster, counting 16007 respondents (around 45% of the sample), includes individuals who score below average in all forms of participation. Some of them might have sporadic conversations about science topics with friends or family or watch a documentary, but any other contact with science seems unlikely. This first segment seems to group those people who are very far from engaging with science in most forms, which I labeled as *disengaged*. The second cluster, the second biggest with 9682 respondents (around 27% of the total), displays average or below average scores only on the items corresponding to the more active engagement items, whereas the values for the cultural enhancing

Table 3. Mean values of the 12 items across the four clusters and sample means.

	Disengaged (N = 16007)	*Aware* (N = 9682)	*Invested* (N = 6664)	*Proactive* (N = 3560)	Grand Mean
Talk with friends about science	0.74	**2.13**	**2.08**	**2.31**	1.55
Watch documentaries/read science	0.86	**2.29**	**2.21**	**2.35**	1.68
Visit museums	0.35	**1.43**	**1.64**	**2.05**	1.07
Study science in free time	0.15	**0.89**	**1.47**	**2.11**	0.81
Sign petitions/join demonstrations	0.22	0.67	**1.32**	**2.01**	0.73
Attend public meetings	0.11	0.39	**1.16**	**1.98**	0.57
Participate in nongovernmental activities	0.08	0.19	**1.01**	**1.97**	0.47
Contact public authorities	0.07	0.13	**0.84**	**1.83**	0.41
Provide personal data for research	0.25	0.83	**1.56**	**2.09**	0.85
Participate in science projects	0.10	0.28	**1.11**	**2.02**	0.53
Take part in clinical trials	0.14	0.30	**0.97**	**1.74**	0.50
Lend computer to research	0.08	0.10	**0.73**	**1.73**	0.37

All variables vary significantly across clusters with $p < .001$, except for V2 between "aware" and "proactive" ($p < .01$), and V11 between "aware" and "disengaged" ($p < .01$). Bold values denote equal or above the grand mean. N = 35913.

activities are above the mean. This group of respondents represents those who consume science-related contents by watching documentaries, reading about science, and going to museums but do not have frequent direct encounters with science. I label this group the *aware*. The third cluster, comprising 6664 individuals (around 18% of the respondents), includes those respondents who have above-average cultural-enhancing engagement and around average levels of participation in governance-oriented and co-creative activities. Therefore, this cluster is describing *invested* respondents, they engage with science-related knowledge, making use of science in an informative way, and on rare occasions participate in science related activities, especially if aimed at influencing policymaking. Finally, the fourth cluster, including 3560 respondents (around 10% of the total), is the cluster with the smallest size, but also the one with the highest levels of participation for each item. The respondents included in this cluster are fully aware of the opportunities to approach science and use them to gain personal knowledge and actively influence science, both in its production and governance. This is the *proactive* public. Interestingly, the values for the culture-enhancing items, especially talking to friends and family and watching documentaries, are comparable among the three engaged clusters, signaling that if citizens engage in these activities, they do it often. Moreover, especially for the items concerning governance and co-creation of science, the mean levels of engagement rarely exceed 2, reflecting the raw distribution of the respondents across items and response options (visible in the Supplemental Material). Even among those respondents who have the highest levels of engagement, these kinds of activities are mostly practiced occasionally, representing only a marginal way of engaging with science.

Looking at the overall items distribution, it is worth noting that the items related to informative engagement score higher than the others in all clusters, which reflects the distributions of the items shown in Table 1. In addition, the analysis shows the absence of a form of engagement in which members participate more in co-creative and policy-influencing ways than in information-oriented ones. Having a personal and culture-enhancing involvement with science, in which science is understood as good to consume and make use of, seems to be the standpoint on which other modalities of engagement add up. The level of involvement in modes that presume science as an active actor with which a relationship can be woven is crucial to distinguish the clusters. Last, those items assumed as examples of citizen science activities do not show any peculiar pattern across clusters. Respondents' scores on those items mirror those on the science governance items, indicating the lack of differentiation between these two types of participation.

Post hoc clusters' profiles

To address the third research question on the clusters' characteristics, I decided to map these types of engagement across sociodemographic indicators and other science preferences. In all, it can be observed that the respondents included in each cluster significantly and substantively differ in their demographic characteristics and other science-related attitudes. The results are shown in two sections below. These are descriptive analyses and cannot be interpreted in causal or predictive terms, and further analysis is needed to investigate the predictors of science engagement.

Demographic characterization. The distribution of sociodemographic indicators across clusters describes a sample in which the least engaged also have lower social status and vice versa. Indeed, the cluster of the *disengaged* gathers quite clearly respondents from medium-low social strata. At the same time, the *invested*, the cluster with high cultural engagement and average "active" engagement, includes members with a rather higher sociodemographic profile. It seems interesting to highlight, however, that the most engaged group does not stand out from the others, but the most noticeable difference is between the group of the nonengaged and all others. Table 4 reports values for each cluster.

In detail, the *disengaged* have noticeably high percentages of respondents that are female, older, living in rural or small towns, employed as manual workers, or retired. Compared to the others, this group includes more respondents who are religious, stopped their education at a younger age, have less educated parents, and use the Internet less often or do not have access to it. The *proactive* cluster, instead, shows the highest percentage of respondents selecting male and nonbinary options (although the differences across the active clusters are not major), younger, living in big towns, and being students. Compared to other active clusters, their parents as educated, they are slightly more religious and use the Internet as frequently. The *aware* are equally divided between males and females, predominantly in the second half of their lives, equally distributed across living areas, and show higher percentages of respondents employed in white-collar jobs, managerial positions, or retired. They have stopped education at a later age, are not remarkably religious, their parents are well educated, and they are frequent Internet users. Finally, the *invested* are also equally divided between males and females and the age categories, prevalently living in medium or big towns and with the highest percentage of respondents employed as managers. They stopped their education at a later stage than the other active clusters, are not very religious, have educated parents, and have a high frequency of Internet use.

Science interest and beliefs. The indicators I selected for this analysis refer to: impediments to engagement, interest in new scientific discoveries and technological developments, appropriate level of public involvement in decisions about science and technology, views on the main relevance of experts' advice or public opinion in decisions about science and technology, familiar closeness to science, and scientific knowledge. Of all the items included in the questionnaire, I chose these above because conceptually they are most closely related to science engagement, and, thus, allow to grasp the nuances of the picture painted by the clustering. Table 5 reports the percentages of respondents across the four clusters in each category of the selected variables.

Table 4. Demographic variables.

Variable	Answer option	*Disengaged* (*N* = 16007)	*Aware* (*N* = 9682)	*Invested* (*N* = 6664)	*Proactive* (*N* = 3560)
Gender	*Male*	45	51	52	53
	Female	55	49	48	46
	Nonbinary	0	0	0	1
Age	*15–34*	23	24	29	37
	35–54	34	37	36	37
	55 +	43	38	35	26
Area of living	*Rural*	37	30	29	28
	Small/medium town	35	36	35	29
	Big town	28	34	36	43
Current job	*Self-employed*	7	8	9	10
	Manager	10	22	24	21
	Other white collar	14	15	13	12
	Manual worker	23	14	14	18
	Homemaker	6	3	3	5
	Unemployed	7	5	5	5
	Retired	26	23	19	13
	Student	7	10	13	16
Education	*15*	14	3	3	9
	16–19	50	27	24	30
	20+	28	58	58	44
	Still studying	7	11	14	16
	No full-time education	1	1	1	1
Religiosity	*Not very religious*	26	41	37	28
	Not religious	45	42	45	46
	Very religious	29	17	18	26
Parents' education	*Low education*	34	18	15	17
	Secondary	41	32	32	31
	Higher education	25	50	53	52
Internet use	*Everyday*	80	97	94	89
	Often/sometimes	7	2	4	8
	Never	11	1	2	3
	No internet access	2	0	0	0

Percentages of respondents per answer category for categorical variables and means for continuous variables for each of the four clusters.
For categorical variables, statistical significance was calculated using χ^2 for all answer options in each variable. All differences are significant across the clusters ($p < .001$). For continuous variables, differences across clusters are significant at $p < .001$, except for religiosity between "disengaged"—"proactive" and "invested"—"aware" ($p < 0.01$). No significant difference was found in Education between "proactive"—"disengaged" and "aware"—"invested"; parent's education between "proactive" and "invested." $N = 35913$.

Once again, the main discrepancy in the responses can be observed between the *disengaged* cluster and all others. However, when it comes to science attitudes, similarities seem to appear between, on the one hand, *invested* and *aware*, and on the other, *disengaged* and *proactive*, especially when it comes to opinions about the role of the public in decision-making. The fact that the most and the least engaged groups score similar responses in these items is fascinating; however,

Table 5. Attitudinal variables.

Variable	Answer option	*Disengaged* (*N* = 16007)	*Aware* (*N* = 9682)	*Invested* (*N* = 6664)	*Proactive* (*N* = 3560)
Lack time	*Selected (ref. not selected)*	35	46	49	39
Lack financial resources	*Selected (ref. not selected)*	18	20	25	29
Lack interest	*Selected (ref. not selected)*	45	23	20	21
Lack information on act	*Selected (ref. not selected)*	26	38	36	29
Lack scientific knowledge	*Selected (ref. not selected)*	42	43	35	27
Lack activities	*Selected (ref. not selected)*	17	26	28	29
Feeling of not being welcome	*Selected (ref. not selected)*	13	15	15	17
Privacy concerns	*Selected (ref. not selected)*	12	19	19	23
Interest in science	*Not at all interested*	27	5	5	7
	Moderately interested	54	51	47	41
	Very interested	19	44	48	52
Public involvement in decision-making	*Public opinion should be main concern*	8	5	5	8
	Public should be consulted	28	30	32	30
	The public should be informed	55	60	57	52
	The public does not need to be involved	9	5	6	10
Public governance	*Decisions should be based mainly on the advice of experts*	73	81	79	68
	Decisions should be based mainly on what the majority of the people in a country thinks	27	19	21	32
Closeness to science	*Not close (ref. not selected)*	93	78	70	61
	Family (ref. not selected)	5	14	18	17
	Personal (ref. not selected)	3	9	15	25
Science literacy	*0–5 correct*	36	15	20	30
	5–8 correct	53	55	49	50
	8–10 correct	11	30	31	20

Percentages of respondents per answer category for categorical variables and means for continuous variables for each of the four clusters. *N* = 35.913.

the mechanisms that led these respondents to their answers might explain this similarity. The present analysis is not able to examine underlying explanations, and further research is encouraged to disentangle this relationship.

Among the impediments to engagement, it can be noticed that overall, those seemingly more relevant are lack of time, interest, information on activities available, and scientific knowledge. Among the *disengaged*, the main barrier to engagement seems to be a lack of interest (mentioned by 45% of the respondents), followed by lack of scientific knowledge (42%) and of time (35%). It is less easy to indicate the most pressing impediments for the most engaged group, the *proactive*, as their selections are more spread out, but certainly the most relevant is lack of time (selected by 39% of the respondents), followed by lack of information (29%), of activities (29%), and of financial resources (29%). The *aware* report mainly the lack of time preventing them to engage (selected by 46% of the respondents), followed by missing scientific knowledge (43%), and information on the activities (38%). For the *invested*, the main issue preventing participation is the lack of time (selected by 49% of the respondents), followed by lack of information on available activities (36%) and of scientific knowledge (35%). Those who already engage with science to some extent report instrumental barriers preventing their participation, such as time or information on available activities, whereas those who do not mention more personal reasons, such as lack of interest or adequate scientific knowledge.

Following this pattern, when it comes to general interest in science, the *disengaged* are the group with the most people having no interest (27%) and the *proactive* the one with the most people being very interested (52%). The *aware* are those with the fewest people scoring lowest (5%) together with the *invested* who are split between moderately to very interested (47% and 48%). Coming to the two items on the level of public participation and the experts' role in decision-making, most of the sample favors mild participation of the public (which should be informed or at most consulted) and the leading role of experts' advice, but there are interesting nuances. The *disengaged* and the *proactive* groups are in higher favor of grounding decision-making on what people think (around 10 percentage points of difference with the other two clusters), even if they have relatively higher percentages of people replying that the public should be just informed or not involved at all in decision making (around 5 percentage points of difference with the other two clusters). Sharper differences between the least and most engaged groups would be expected in their opinions toward the participation of citizens and experts in decision-making about science and technology. For example, the proactive could be expected to favor more clearly experts' lead in decision-making due to their closeness to science, or the disengaged not to show a clear pattern due to their lack of interest. Instead, the similarity of opinions between these groups signals that more work must be done to understand and disentangle motives and effects of (dis)engagement with science. This descriptive analysis cannot provide support for any speculative interpretation nor can the data employed can give information on the drivers of these answers.

Finally, it can be noticed, by now unsurprisingly, that the *disengaged* are those with more people not close to science (93%) and the highest percentage of people with low scientific knowledge (38%). The *proactive* respondents are those with the highest percentage of respondents personally close to science (25%), but their science literacy does not seem to be strikingly better than the other clusters (30% answered 0–5 correct answers). Obversely, the *aware* seem to be knowledgeable (86% answered between 5 and 10 correct answers), but rather distant from science (78% of not close). Finally, the *invested* have more people close to science than the *aware* (15% personally close) and seem to have the same level of science knowledge (31% answered 8–10 times correctly). The distribution of science literacy across clusters, especially the value for the *proactive* group, is remarkable considering the expectation of a relationship between engagement with science and science knowledge (Weingart et al., 2021). So far, however, this has been an assumption that seemingly needs further investigation. Moreover, these results are in line with what already observed with Eurobarometer data from 2005 on engagement and knowledge in biotechnology (Gaskell et al., 2006), possibly highlighting that despite the increase of the emphasis on engagement and the activities offered, its relationship with knowledge is nevertheless not straightforward.

6. Discussion and conclusion

This study contributes to the literature on public engagement with science in three ways.

First, this study focuses on characterizing different types of science engagement activities and publics, without including other science attitudes in the definition of the clusters, as done in previous literature. By employing an extensive list of engagement activities, it offers new insights toward a more complete understanding of who engages with science, and how. The data structure and analysis methods employed, however, led to the production of four categories that can be placed on a hierarchical scale of engagement. *Disengaged, aware, invested*, and *proactive* align on a pattern from lowest to highest intensity of engagement. Drawing on the literature on typologies of engagement, the science publics identified here can be described according to some of the core criteria as the level of power redistribution (Arnstein, 1969), the nature and flow of information (Rowe and Frewer, 2005), or the actors involved in the activities (Bucchi and Neresini, 2007). Going from the least to the most involved publics: the *disengaged* are those people completely out of the scientific conversation, the *aware* public mainly use science as a provider of information and entertainment, the *invested* make use of science and moderately engage in a dialogue with it, and finally, the *proactive* are those with the highest levels of interaction and exchange with science and the scientists. Sorting the clusters according to their size, the same order appears. The groups that are more enabled to speak back to science (Gibbons, 2000), that is to establish a counter flow of information, are also the smallest ones in size and include a considerable number of respondents personally close to science. Similar findings have been observed in previous research on different science topics or settings. The patterns of engagement with biotechnology highlighted in the report on the Eurobarometer 2005, despite the employment of a different set of indicators, present a similar distribution of respondents (Gaskell et al., 2006). In a study of public attitudes toward science and technology policymaking in Japan (Okamura, 2016), the types of publics highlighted, although three and not four, echo in characteristics and size those shown here. However, confronting the typology presented in this article with other analyses of science publics based on other attitudes, it is interesting to note the absence among the latter of a large category comparable to the *disengaged*. Taking two international typologies focusing on dispositions toward science and science literacy as examples (Kawamoto et al., 2013; Pullman et al., 2019), although they differ in their operationalization and outcomes, neither finds a wide category of science-disinterested, skeptical, or illiterate people. This is relevant as it suggests caution in interpreting the *disengaged* as completely separated from the scientific discourse. Not engaging with any of the activities considered in this study might not directly imply the scarcity of any disposition toward science and might even suggest the need to revise the way engagement is operationalized. Reflecting on the consequences of the common ways of measuring engagement with science and exploring in more depth the relationship between engagement and other science attitudes represent promising research avenues that could have important consequences for how we imagine science publics.

Second, it provides the first empirical evidence on the relationship between activities of co-creation and citizen science and other governance-oriented initiatives. The PCA analysis did not find that initiatives of citizen science formed a component of their own but were part of a component characterized by general engagement. As this is the first Eurobarometer in which these items are included, it could be the case that these turned out to imperfectly capture the concept, especially in a cross-national setting. Otherwise, this outcome indicates that when it comes to people's reported behavior, it is difficult to disambiguate between a governance type of engagement and activities of citizen science. This result resonates with the citizen science literature in which the line between the two seems blurry. As an example, the typology of citizen science elaborated by Wiggins and Crowston (2011) includes in the definition of citizen science a type of engagement in which citizens try to influence local civic agendas using science. Further research is needed to investigate this result and understand what its implications are.

Third, it provides insights into the distinctive demographic and attitudinal traits of different ways of approaching science. The respondents in the cluster scoring lowest in engagement show a rather disadvantaged profile: they are older, manual workers and females, and stayed in full-time education for fewer years, whereas the more engaged ones seem to be more privileged. Even if this result was expected given previous research on science access and inclusion (e.g. Dawson, 2018), it represents an indicator of the fact that when it comes to activities considered the goals of power redistribution, co-creation, and nonscientists' involvement are still far from being achieved among the lower strata of society. However, it is also interesting to notice that this is mostly true for the clusters with high scores on the informative engagement items, whereas the most engaged cluster shows a more mixed demographic profile. On the side of science preferences and attitudes, the major impediment to participation for the least engaged is lack of interest, as already shown in previous research (e.g. Ipsos MORI, 2011). However, settling on this explanation would only reiterate an approach to science inclusion based on the double-deficit perspective (Dawson, 2014), attributing the blame for the disengagement to the disengaged themselves. Future research should aim at advancing our understanding of the origins and correlates of this lack of interest among the most disadvantaged groups of society, as well as the ways in which societal institutions might remedy this situation. A second puzzling result in this battery is the similarity in response patterns between the most and the least engaged groups for those questions investigating views on citizen involvement in decision-making and public governance of science, and their respective difference from the other two. Compared to *aware* and *invested, disengaged* and *proactive* have higher percentages of respondents preferring minor public involvement in decision making, but at the same time (relatively) higher percentages arguing that what the majority of people in a country think should be the main concern in science governance. These responses do not wildly deviate from the overall trend but are interesting to underline. Indeed, given the common expectation, nourished by the deficit model theory, that engagement with science is associated with more favorable attitudes toward science (Weingart et al., 2021), it is to be expected that favor toward experts' lead in decision-making would be higher among those who engage more. This might not be the case, just as those who engage the most do not seem to have significantly higher levels of scientific literacy. Given the limits of the present analysis, only a speculative hypothesis can be put forward to explain these results. It could be the case that the equation between science engagement and favorable attitudes is flawed, or that the reasons for engaging derive not only from science enthusiasm but also from critical stances toward science, or even that it is insufficient to interpret engagement incrementally. As mentioned, nothing can be said from the present analysis about the mechanisms that prompted these answers, and a replication of these results is encouraged.

This study has three limitations, representing avenues for future elaborations on science engagement. First, the data employed in the analysis refer to attitudes toward *science and technology* without further specification, but we know that people relate differently to science in general and specific realizations of it (Achterberg et al., 2017). Therefore, these results are not to be extended beyond general science and technology, in which case additional research is advised. Second, the questions investigating preferences toward science decision-making do not differentiate between technical science issues and social issues concerning science. This conceptual differentiation is crucial as it implies a very different role for the engaging public (Wynne, 2007), and may have consequences on how participation is understood, both by the public and by science. Research in this field and consequent policy solutions might benefit from a more fine-grained elaboration on engagement contexts. The last point that deserves brief argumentation is the method chosen. Cluster analysis is a data visualization tool that is very influenced by the measure of distance, the clustering algorithm, and the dataset used. Therefore, despite the substantial validation performed through the post hoc characterization, these results would gain robustness by repetition with other methods or in other contexts (Aldenderfer and Blashfield, 1984; Hair et al., 2010).

In all, this study is a contribution to the understanding of the relationship between the European public and science engagement. I have observed that when it comes to people's engagement choices, activities of citizen science cannot be distinguished from other active forms of science engagement, that the share of the population which does not engage at all with science is still large, around 45% of the sample, that the individuals included in this category mostly have low social status which is not true for those who participate in science in some ways, and that the most and least engaged groups seem to share the same perspective on processes of science decision-making. These results are enlightening on the opportunity structures that are created by the ways in which people make use of engagement possibilities and highlight that the road to achieve widespread and representative engagement is still long. Differences in the possibilities among socio-demographic groups are still present and deserve further attention, for the achievement of the goals at the heart of Public Engagement with Science.

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Data

Special Eurobarometer 561: European citizens' knowledge and attitudes toward science and technology. European Commission, Brussels. (2022). Eurobarometer 95.2 (2021). GESIS, Cologne. ZA7782 Data file Version 1.0.0, *https://doi.org/10.4232/1.13884*.

Data file and related documents (questionnaire) are also retrievable at:
https://data.europa.eu/data/datasets/s2237_95_2_516_eng?locale=en

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Supplemental material

Supplemental material for this article is available online.

Note

1. The Euclidean distance can be described as the straight-line distance between two observations and Ward's method is a hierarchical agglomerative algorithm, which sequentially combines clusters aiming at minimizing the within-cluster sum of squares error for the total cluster solution (Mejlgaard and Ryan, 2017).

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Who engages with science, and how?

An empirical typology of Europeans' science engagement

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Supplemental material

Table of content

1. Distribution of responses across the twelve items

		3 Regularly	2 Occasionally	1 Hardly Ever	0 Never
Talk with friends about science	Freq.	5,817	15,782	6,645	7,669
	Cum.Perc.	16.20	60.14	78.65	100
Watch docu / Read science	Freq.	7,760	15,668	5,627	6,858
	Cum.Perc.	21.61	65.24	80.90	100
Visit museums	Freq.	1,924	11,114	10,529	12,346
	Cum.Perc.	5.36	36.30	65.62	100
Study science in free time	Freq.	2,175	6,709	9,074	17,955
	Cum.Perc.	6.06	24.74	50.00	100
Sign petitions / Join demonstrations	Freq.	1,762	6,486	8,075	19,590
	Cum.Perc.	4.91	22.97	45.45	100
Attend public meetings	Freq.	1,049	4,257	8,821	21,786
	Cum.Perc.	2.92	14.77	39.34	100
Participate in non-gov activities	Freq.	1,006	3,452	7,011	24,444
	Cum.Perc.	2.80	12.41	31.94	100
Contact public authorities	Freq.	798	2,898	6,402	25,815
	Cum.Perc.	2.22	10.29	28.12	100
Provide personal data for research	Freq.	2,089	8,443	7,263	18,118
	Cum.Perc.	5.82	29.33	49.55	100
Participate in science projects	Freq.	1,437	4,110	6,466	23,900
	Cum.Perc.	4.00	15.45	33.45	100
Take part in clinical trials	Freq.	1,037	4,330	6,212	24,334
	Cum.Perc.	2.89	14.94	32.24	100
Lend computer to research	Freq.	911	2,771	5,054	27,177
	Cum.Perc.	2.54	10.25	24.33	100

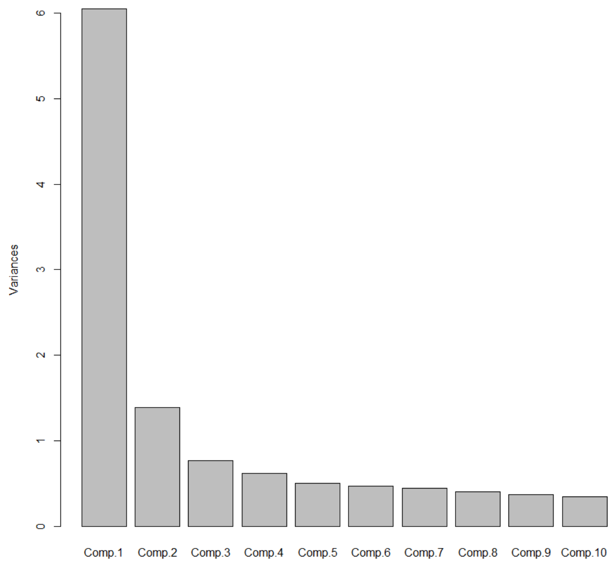
Note: Freq. = Frequencies, Cum.Perc. = Cumulative Percentages; N = 35,913

2. Correlation matrix

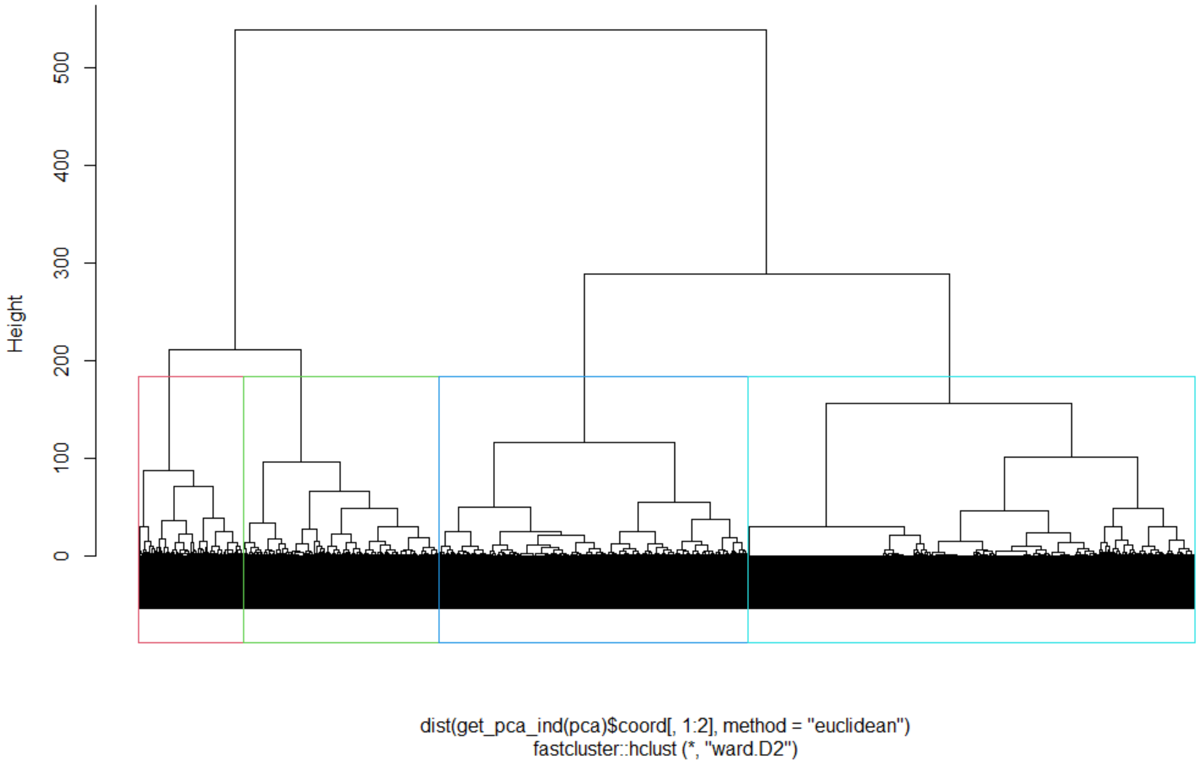
a. Talk with friends about science	1.00											
b. Watch docum. / Read science	0.71	1.00										
c. Visit museums	0.54	0.57	1.00									
d. Study science in free time	0.49	0.49	0.56	1.00								
e. Sign petitions / Join demonstrations	0.38	0.37	0.45	0.45	1.00							
f. Attend public meetings	0.39	0.38	0.50	0.57	0.54	1.00						
g. Participate in non-gov activities	0.34	0.31	0.44	0.52	0.54	0.67	1.00					
h. Contact public authorities	0.29	0.27	0.40	0.47	0.50	0.61	0.66	1.00				
i. Provide personal data for research	0.44	0.42	0.47	0.47	0.46	0.47	0.47	0.45	1.00			
j. Participate in science projects	0.37	0.34	0.42	0.53	0.44	0.56	0.57	0.53	0.50	1.00		
k. Take part in clinical trials	0.28	0.27	0.37	0.40	0.39	0.44	0.46	0.46	0.57	0.47	1.00	
l. Lend computer to research	0.25	0.23	0.34	0.43	0.40	0.49	0.52	0.53	0.44	0.56	0.48	1.00
	a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*	*i.*	*j.*	*k.*	*l.*

The table shows Pearson correlation coefficients among the twelve items. The highlighted correlations are those that, according to the theory, are expected to stand out signaling the three types of engagement activities. It can be noticed these correlations are high indeed, but so are those outside the highlighted areas, with the first four items being the only exception.

3. Castell's Scree Test



4. Dendrogram



Graphic representation of the clusters. The clustering algorithm groups units on the basis of their distance calculated on the output from the principal component analysis. The units in this case are all the individuals in the dataset (valid cases = 35,913), hence the black bar showing at the bottom of the graph.

Chapter 5
Article B

Under review at *Public Understanding of Science*. Received a "revise and re-submit" on November 16th 2023.

Socio-economic status and authority deference.
Understanding science (dis)engagement in Europe.

Abstract

It is repeatedly observed that science engagement is more common among members of the public with a more privileged socio-economic profile, however little evidence is put forward on the elements contributing to this outcome. This article adds to the literature by exploring the role of technocratic tolerance. A Structural Equation Model on Eurobarometer516 data investigates if favoring expert guidance over public participation in decision-making on science-related issues mediates the relationship between people's socio-economic status and two forms of science engagement. Results show that higher socio-economic status is associated with greater engagement and more reliance on experts' deliberation. Favoring experts over public participation in decision making is also associated with more informative engagement and less general engagement, however its mediating role is rather weak. This analysis contributes to the debate on the drivers of disengagement among social classes, moving from a deficit perspective toward a nuanced comprehension of the phenomenon.

Keywords: science engagement, socio-economic status, technocratic tolerance, science attitudes, Structural Equation Modelling

1. Introduction

Public engagement represents a vital element of the relationship between science and society. It is attributed a crucial role in improving science access, promoting science acceptance, empowering citizens, and diversifying and expanding science itself (Weingart et al., 2021; Stilgoe et al., 2014). Indeed, opening up (Stirling, 2008) science to non-professionals is meant to positively impact both science and the public. Moreover, getting acquainted with scientific knowledge is an important instrument for citizens to make informed choices and live better lives in modern societies (Levinson, 2010; Gaskell et al., 2005). At the same time, welcoming diverse knowledge would not only make science more inclusive, but it could also contribute to its further development.

Given this potential, various activities and tools have been crafted to enhance engagement, but lately, research has questioned the composition of the public participating in such activities. Indeed, a diverse audience is crucial for these instruments to meet the goals of empowerment, inclusion, and innovation for which they were developed. However, studies have shown that the typical participants are usually far from representative of the entire population (for an overview on citizen science: Paleco et al., 2021), with some socio-economic groups poorly represented (Makarovs and Achterberg, 2018). The least engaged individuals are often described as belonging to the more disadvantaged groups of society (Yosso, 2005), whereas participation is more likely among middle-aged, middle-class, educated, white males (Archer et al., 2015). A typical explanation offered for this engagement gap refers to barriers to engagement. In understanding what prevents certain people from participating, lack of time, knowledge, and especially interest are often reported among the suspects (Falk et al., 2007, Dreyer et al., 2021). However, the fact that the lack of interest and, more in general, the distance from science is peculiar to a specific, marginalized part of the population, is an indicator of a detachment between science and part of society which still deserves deeper understanding. Studies of the determinants of lack of interest and disengagement among marginalized groups of (European) societies suggest that part of the explanation might reside in how science is structured and organized. This is reflected in the fact that a sense of non-belonging, exclusion, and lack of representation can lead certain parts of the lay public to avoid contact with science (Dawson, 2014a; Godec et al., 2022), which could be addressed mainly through intervening in the structure of science rather than on the attitudes of the public. In this study, I offer an additional interpretation by focusing on individual attitudes that might be determined by social status and influence the extent to which people engage. I investigate how the relation between socio-economic status and engagement with science is influenced by individuals' views on who should be involved in science related decision-making. Since its introduction, a large part of the literature and practice on public engagement with science has concerned its deliberative attributes, which is reflected in the measures of engagement employed in the Eurobarometer surveys on science and technology (e.g., data from Eurobarometer 2010 used in Makarovs & Achterberg, 2018). Therefore, one would expect people's preferences concerning deliberative decision-making to play a relevant role in their engagement with science. The results of this study contrast with this expectation, as they highlight a split between deliberative participation preferences and effective engagement across social groups.

Drawing from social psychology and status legitimation theory, the preferred level of participation in science decision-making might vary according to an individual's socio-economic status, thus influencing their different levels of engagement with science. As is historically the case for civic participation (Lijphart, 1997), people from more disadvantaged socio-economic backgrounds might tend to consider citizens' engagement in decision-making to be less compelling than their more advantaged counterparts and, therefore, engage less. In this paper, I hypothesize that science is no exception and expect individuals with a disadvantaged background to defer more to experts' opinions and favor less public involvement with decision-making and, therefore, engage less. I explore this mechanism using Structural Equation Modeling on the latest Special Eurobarometer (2021), focusing on "*knowledge and attitudes towards science and technology*". Results highlight that socio-economic status is an important predictor of science engagement and moderately related to people's preferred level of public – or expert – participation in science decision-making. However, the latter's mediating role is not as relevant as expected. The implications of these results and additional analyses exploring the mediating role of other science attitudes are discussed in the last section.

2. The stratified reality of public engagement

Public engagement with science is, in essence, a multidimensional concept. Definitions of public engagement are contingent and contextually adjusted to its elements on the types of activities, objectives, audience, the role of the public, and the products of the exchange (Rowe and Frewer, 2005; and for an overview: Weingart, 2021; Kumpu, 2022). For a concept so ambiguous, it is also challenging to elaborate on unique criteria for its evaluation (Emery et al., 2015). When considering the goals for which public engagement with science was introduced, the breadth of its reach becomes a fundamental indicator for its assessment. Indeed, this is to be understood not only as how many people engage with science and how often but also if the participants are representative in their characteristics of the entire population. Studies show that this last criterion, in addition to being debated in evaluation literature (see Emery et al., 2015), is rarely met. Public engagement with science and technology seems to reflect patterns of social stratification. In its sociological definition, stratification here is the division of social groups based on power, status, and wealth, which generates inequality (Grusky, 2019).

In studies on citizen science activities, it has been observed that sociodemographic features such as educational level, gender, age, and ethnicity (Pandya et al., 2019; Wright et al., 2015) distinctly characterize the engaged and disengaged groups. Generally, people with a higher socio-economic profile are more likely to be among the engaged public than the more disadvantaged (Paleco et al., 2021, Losi, 2023). Interestingly, a similar link has also been observed in studies concerning forms of civic and political engagement. As an example, when it comes to voting behavior, a study across several European countries has highlighted how non-voting is higher among less educated people (Hadjar and Beck, 2010). Therefore, science may not be a special case in its engagement outreach, being less popular among the more marginalized groups of society. With the present data, I am not able to investigate if the patterns of engagement are the same among science and other social issues and if the (dis)engaged publics match their characteristics; it is something I leave for future research. Nevertheless, given the existing evidence, the starting hypothesis of this study is:

H1. People belonging to less advantaged socio-economic groups are less likely to engage with science and technology.

To understand then how different social groups get to (dis)engage with science, in the following sections, I offer further arguments aiming at unpacking this relationship, focusing on the role of individual technocratic tolerance.

2.1 Experts' decision-making and public deliberation

In arguing that participatory views towards decision-making might mediate part of the relationship between sociodemographic background and science engagement, I draw on the social psychology literature. In particular, I consider system justification theory, "the process by which existing social arrangements are legitimized, even at the expense of personal and group interest" (Jost and Banaji, 1994:2). This theory was developed in the context of research on intergroup relations, stereotypes and prejudices and primarily applied in the study of economic rationality and political ideologies. What struck researchers was the apparent irrationality by which low-income groups would not show support for economic redistribution measures aimed at easing inequalities and instead favor ideologies sustaining positions against their interests. Counter to the idea that societies are organized in imposers and opponents, the system justification framework puts forward the psychological and social mechanism by which people are led to confer legitimacy to the current social order and to regard it as natural and inevitable (Jost, Banaji and Nosek, 2004:887). According to this theorization, people are expected to tend to perceive the power structure of the society in which they are living as a given, even when, from the outside, this seems to be to their disadvantage (Buchel, Luijkx and Achterberg, 2021; Jost, Banaji and Nosek, 2004).

Empirical studies have highlighted how individuals with low sociodemographic status are more likely to rationalize social and economic differences between groups (Buchel, Luijkx, and Achterberg, 2021; Friesen et al., 2019; Jost, Banaji, and Nosek, 2004). In addition, a subjective sense of powerlessness seems to be associated with enhanced justification tendencies. A series of experimental studies on justification towards authority, hierarchy, and government observed how individuals experiencing relative powerlessness are more prone to perceive the related power structures as just and legitimate (van der Toorn et al., 2015). Moreover, people from more advantaged sociodemographic backgrounds might be more likely to adopt attitudes diametrically opposed to the current power structure. Indeed, their ability to reflexively (Beck et al., 1994) approach reality might push them towards challenging authorities and supporting science democratization, as has been previously observed (Makarovs and Achterberg, 2018).

When it comes to public attitudes towards science, empirical studies have shown how these can be predicted by personal characteristics, e.g., political affiliation (Gauchat, 2012), religiousness (McPhetres and Zuckerman, 2018), or state of life (Fuglsang, 2022). At the same time, public opinion on the appropriate level of public participation in decision-making on matters of science and technology has been investigated in studies about the trust or authority perception of science or scientists (Brossard and Nisbet, 2006; Howell et al., 2020). Evidence suggests that the relationship between education and participatory views towards science and technology seems to be positive, with the more educated being more prone to favor democratic control of science (Makarovs and Achterberg, 2018), although evidence is mixed (Brossard and Nisbet, 2006).

Drawing on this argumentation, I expect that:

H2. People belonging to less advantaged socio-economic groups are less supportive of democratic governance of science and technology and contextually more supportive of experts' decision-making on science and technology issues.

In this article, *experts* refers to the professional figures traditionally in charge of decision-making, either scientists or other decision-makers. However, it is not specified further to match the empirical measures. By *democratic* or *public governance* of science, I mean the participation of laypeople in actions of decision-making.

The link between these preferences and science engagement has yet to be investigated, though the adjacent literature allows us to formulate some expectations. It has been observed that individuals with higher levels of education are more engaged with science in a deliberative manner, that is, through activities designed to influence decision-making on scientific and technological issues, and, concomitantly, they favor more democratic decision-making on scientific issues (Makarovs and Achterberg, 2018). At the same time, views on participatory decision-making in science and technology have been studied alongside deferential attitudes toward scientific authority (Howell, 2020). This concept is close to the system justification introduced in the previous paragraphs, as it captures the spontaneous display of acceptance of hierarchy by the non-elite as the natural configuration of society (Pocock, 1976). In political behavior literature, similar attitudes have already been studied when investigating the determinants of civic participation and institutional trust under the concept of *technocratic tolerance*. This expression identifies the "support for the government by technique" (Lindstam, 2014:16), and it has been observed to be associated with educational level and voting behavior. Less educated individuals are more in favor of the inclusion of experts in government, which is linked to lower participation in elections (Lindstam, 2014). In another study, it was observed that more distrustful and less politically interested citizens have higher support for technocracy (Bertsou and Pastorella, 2017).

The theories and the supporting empirical evidence introduced above seem to be capturing different shades of the same complex mechanism that brings certain social groups to accept social structure as given and, therefore, take little to no action to enter the stage. Literature on political participation reports that citizens' ideals of how decision-making processes should work are linked to their civic participation choices (Bengtsson & Christensen, 2016). Therefore, I investigate here the possibility of applying this line of reasoning to science participation as well, with the last hypothesis being as follows:

H3. People who are less supportive of democratic governance of science and more supportive of experts' decision-making on science and technology issues are less likely to engage with science.

3. Data and Methods

The data employed in this study is the latest Special Eurobarometer 516 on "*European citizens' knowledge and attitudes towards science and technology*". Face-to-face interviews were coordinated by the European Commission between April and May 2021, and the final dataset consists of 37.097 respondents aged 15 and over across 38 countries.

The model built by the hypotheses is displayed in Figure.1 – included in the results section – and has been tested with Structural Equation Modeling (SEM). The main dependent variable, science engagement, is a latent variable, and the main independent variable and the mediator, socio-economic status (SES) and technocratic tolerance are observed variables. Details on the specification of these variables can be found below. The analysis was performed using R (version 4.2.2) and the dedicated *lavaan* package (version 0.6-15). The models were run using the Weighted Least Square Maximum Variance estimator (WLSMV). This estimator was chosen following recommendations from the literature (Gana & Broc, 2019) as it does not assume the normality of the data, and it is appropriate with ordinal or categorical data with at least four answer categories that are treated as continuous. Listwise deletion was employed to treat missing data, resulting in a final sample size of 33.393. The model fit was assessed through the fit statistics indicated in the literature (Kline, 2015; Gane & Broc, 2019): Comparative Fit Index (CFI>0.90 for acceptance), Tucker Lewis Index (TLI>0.90), Standardized Root Mean Square Residual (SRMR<0.05), Root Mean Square Error of Approximation (RMSEA<0.07). This study was preregistered on the OSF webpage[3].

3.1 Main dependent variable

Science engagement has been measured through a battery of twelve items developed by field experts as representative of various forms of public engagement with science and technology. Including different possibilities of participation allows for a more comprehensive analysis of the concept of engagement, allowing for its multidimensionality. Indeed, to understand the dimensions underlying this battery, following Ben-Eliyahu and colleagues (2018), I have explored different configurations of the science engagement items through various measurement models. The performed confirmatory factor analyses (CFA) resulted in the identification of a bifactorial solution (Gana & Broc, 2019), reported in Table.1. One factor includes only items identifying an informative kind of engagement, hereafter *informative engagement*. The other factor includes all the engagement items identifying an encompassing general engagement, although it is defined more strongly by those items referring to activities aimed at influencing policymaking and science co-creation, hereafter *general engagement*. The resulting factors are reliable with McDonald's omega (for details see: King et al., 2021) of respectively 0.75 and 0.92 and have *metric* measurement invariance across countries. These two factors will be used jointly in the subsequent analysis to measure science engagement. This result is aligned with what has emerged in a previous article building a typology of science engagement using the same battery and dataset; therefore, I employ the same wording and refer to it for the discussion of these two forms of engagement (see Losi, 2023). Finally, this operationalization slightly deviates from what was stated in the

[3] OSF view only anonymized link: https://osf.io/h52q4/?view_only=ad63f2cebdac4e1c8a701ee0da615564

preregistration, and the analysis process and motivation can be inspected in the Supplemental Materials section 1.

Table.1 Results of the Measurement Model on the observed items for engagement.

Latent Variable	**Informative Engagement**			**General Engagement**		
Items	Estimate	St. Err.	St. Est.	Estimate	St. Err.	St. Est.
Talk with friends about science	1.000		0.637	1.000		0.491
Watch document. / Read science	1.203	0.015	0.753	0.956	0.009	0.461
Visit museums	0.559	0.008	0.383	1.141	0.011	0.603
Study science in free time	0.358	0.007	0.241	1.308	0.013	0.679
Sign petitions / Join demonstrations				1.288	0.014	0.685
Attend public meetings				1.355	0.015	0.819
Participate in non-gov activities				1.195	0.014	0.751
Contact public authorities				1.039	0.014	0.969
Provide personal data for research				1.505	0.016	0.758
Participate in science projects				1.006	0.014	0.605
Take part in clinical trials				0.890	0.013	0.594
Lend computer to research				1.238	0.014	0.716

Fit indices: CFI=.995, TLI=.991; RMSEA= .037, SRMR=.031. Estimator: WLSMV. N=35913

3.2 Main independent variable

Socio-economic status is measured here as an additive scale composed of personal educational level, parent's education, job prestige, and self-reported social level. I have chosen this formulation to consider various elements of the presence or absence of prestige and resources that define social status. Measures of SES are debated in the literature, and different operationalizations and arguments have been put forward. Single items are often used depending on which aspects of individuals' societal position are evaluated by the research questions. These items are objective and subjective indicators of cultural and economic capital, such as education, income, job prestige, or self-assessed social class (Diemer et al., 2013). Composite indicators are less used as it is argued that they can lead to unclear interpretations of the results by masking the effects of the single indicators (Oakes & Rossi, 2003). However, in this study, I am interested in the effect of the heterogeneous set of experiences with which individuals live their daily life, and the latter operationalization seems to be able to capture this complexity. Since, in the hypothesis, I do not refer to any specific element of socio-economic status; I have chosen to build a scale of items capturing objective and subjective measures of economic and cultural status and background. The scale includes the following standardized items: individual level of education, which is included in the questionnaire as the respondents' age at the end of full-time education; parents' level of education, measured as the maximum level between father and mother; job prestige mapped through the Erickson Goldthorpe Portocarero (1979) prestige scale according to the guidelines by Ganzeboom & Treiman (2003), and self-reported social level. The resulting scale has a McDonald's omega of 0.60 and can be considered reliable. In order to control for variance in the scale across countries, I have included the measure's group-centered version (Enders & Tofighi, 2007).

This scale formulation deviates from what was stated in the preregistration, and details about the selection criteria and the elaboration of variables are available in the Supplemental Materials section 2. For completeness, models with the corresponding items included individually are also included in the Supplemental Materials section 2.c. The results vary in magnitude, but the substance of the effects does not differ from the analysis presented below.

3.3 Mediating variable

Technocratic tolerance is captured by two items included in the survey. One is a dummy variable investigating whether decisions about science and technology should be based mainly on *experts' advice* or *what most of the people in a country think*. The other provides respondents with four categories, among which indicate the appropriate level of public involvement in decision-making about science and technology. The categories are: *public opinion should be the main concern*, *the public should be consulted, and public opinion should be seriously considered*, *the public should be informed*, and *the public does not need to be involved*. The measurement model (CFA), including only these two variables, is problematic, as it employs them singularly in the main model. However, as they measure adjacent concepts, namely the involvement of the public's perspective in science decision-making, I have decided to join them as a unique indicator. Furthermore, I included them in the main model as an additive scale where higher values indicate less public participation in decision-making and more experts' deliberation. A cross-tabulation to inspect the matching between the responses to these two variables and models in which each of them is included separately can be found in the Supplemental Materials section 3, together with the three outcomes from analysis models, including the two indicators one by one and jointly. The results vary in magnitude and significance but are not remarkably different from those presented below.

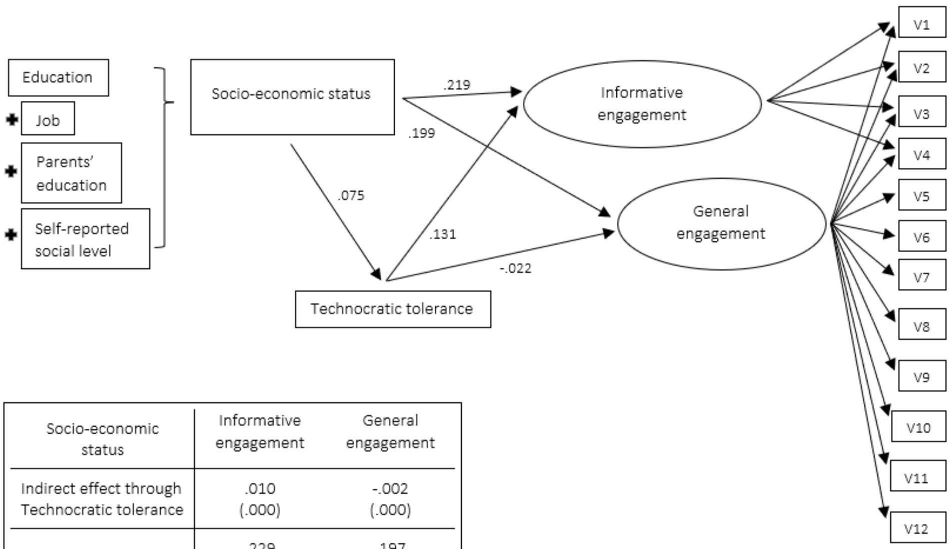
3.4 Controls

The structural model includes gender and age as control variables for each endogenous variable, corresponding details can be found in Supplemental Materials section 4. Moreover, since the dataset is composed of individuals clustered in countries, I have estimated an additional fixed-effect model to acknowledge the data's nested structure. At the time of writing this article, including fixed effects is not straightforward in SEM software, and even less so is the estimation of clustered standard errors (Silva et al., 2019). In this analysis, I have accounted for clustering by adding dummy variables for each of the 38 countries in each equation, leaving one out (UK) as a reference category. The results after including these dummy variables are not remarkably different from the model without them, but the fit indicators decrease substantially. Therefore, I have decided only to include the analysis with fixed effects in the Supplemental Materials section 5 and 7 and show the results from the pooled sample in the main text.

4. Results

Figure.1 displays the model tested and described by the hypotheses along with the results from the analysis (standardized coefficients). The items that compose the main independent and dependent variables are shown for clarity. Given their common source in the model, I have fit correlated disturbances for the two engagement latent variables according to the corresponding Expected Parameter Change (EPC) (Saris et al., 2009; Oberski, 2014) of the measurement model. More details can be found in the Supplemental Materials section 1.b. The model in Figure.1 tests to what extent socio-economic status predicts individuals' engagement with science directly and indirectly through favor towards experts' governance of science. According to the hypotheses, I expect SES to be positively related to both forms of engagement (*h1*) but negatively related to technocratic tolerance (*h2*) and this to be negatively related to both forms of engagement (*h3*). Ultimately, I expect SES to have a direct and indirect significant and positive relationship with science engagement through technocratic tolerance.

Figure.1 Predicted model results with fully standardized coefficients. Square windows indicate manifest variables (indicators), circular windows indicate latent variables (factors), and arrows indicate the expected direction of the effects. The bottom-left box shows the calculations for the indirect effects of socio-economic status through technocratic tolerance on both factors of engagement and the total effects, with standard errors in parentheses. All coefficients are significant at $p \leq .001$.



Socio-economic status	Informative engagement	General engagement
Indirect effect through Technocratic tolerance	.010 (.000)	-.002 (.000)
Total effect	.229 (.007)	.197 (.004)

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According to the fit indices listed above, the model fits the data well: CFI = .991, TLI = .986, RMSEA = .036 (robust estimates), and SRMR = .030. As expected, socio-economic status is positively related to both forms of engagement. Having an advantaged socio-economic and cultural profile, defined here as being more educated, coming from more educated parents, having a higher prestige job, and believing to belong to higher social strata, is directly related to more frequent contact with science. This is true for both the general and informative science engagement types and net of the controls, age, and gender. These results support *hypothesis 1*. Socio-economic status is also positively related to technocratic tolerance, in which higher values indicate favor for experts-led deliberations on science and technology-related issues. Respondents belonging to higher social strata tend to prefer a mild public involvement in decision-making, which is not in line with what I expected with *hypothesis 2*. Finally, concerning the relationship between technocratic tolerance and engagement, being more in favor of expert guidance when it comes to issues about science and technology is associated with more informative but less general – and more active – engagement with science. These results provide partial support for *hypothesis 3*. When repeated using the two indicators for technocracy tolerance individually, the analysis – available in the Supplemental Materials section 3 – has similar results. The results concerning *hypotheses 2* and *3* are statistically significant but relatively small, indicating existing but weak relationships. Indeed, the bottom-left box in Figure.1 shows that the indirect effects of Socio-Economic Status on engagement through technocratic tolerance contribute to the total effect in a minor way. Thus, from these results, it does not seem that deferring decision-making to experts on science and technology-related issues contributes to explaining the relationship between socio-economic status and public engagement with science.

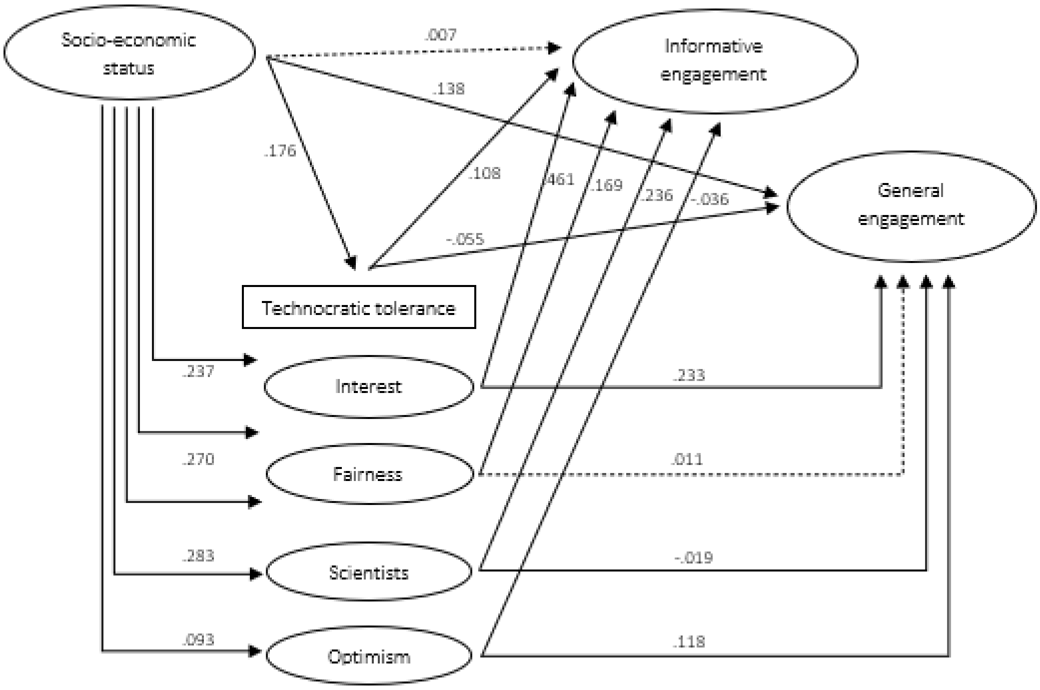
4.1 Extended Analysis

To further explore the relationship between socio-economic status and science engagement, I now undertake an exploratory analysis investigating the mediating role of other science attitudes often employed as explanations for public (dis)engagement with science. I add four science attitudes to the model in Figure.1 in the same mediating role as technocratic tolerance and observe their effect on the direct and indirect coefficients.

The science attitudes I employ are: interest in science, perception of science inequality, perception of scientists, and technology optimism. *Interest in science* is captured by the extent to which respondents are interested in scientific and technological developments, medical discoveries, and the environment. *Perception of science inequality* is identified through the extent to which respondents agree to items indicating that science could benefit everyone but, in fact, it favors only people or countries that are already better off. *Perceptions of scientists* are captured by respondents' agreement to statements stereotyping scientists as not enough objective and accurate or relying on private funding. Lastly, *technology optimism* reflects statements on the positive consequences that science and technology will have on societies in the future. All these are additive indexes that have been included in the structural model of the main analysis. All the items' scales range from less to more positive attitudes, details can be found in the Supplemental Materials section 6.

The fit of this model is still good, although adding elements to the model decreases the fit slightly: CFI = 0.965, TLI = 0.950, RMSEA = 0.057 and SRMR = 0.049. When alternative paths are added, the direct effect of socio-economic status on both engagement factors decreases and becomes insignificant in the case of informative engagement. Its indirect effect through technocratic tolerance on informative engagement decreases slightly, whereas the one on general engagement doubles in size, even if remaining small. The addition of other attitudes towards science thus contributes to explaining the relationship between SES and engagement and adds information to the analysis. Indeed, the coefficients for the total effects of SES on both factors of engagement change noticeably but are distributed differently across the variables in the model. Socio-economic status is significantly and substantially associated with all the mediating variables, with coefficients ranging from .093 in the case of technology optimism to .283 in the case of perception of scientists. However, the mediating factors are not all uniformly and remarkably associated with science engagement. As expected, the one more substantially related to both factors of engagement is interest in science. The coefficients of the indirect paths of SES through this mediator are .109 for informative engagement and .055 for general engagement, which constitutes substantive parts of the total effects. In addition, perceiving science as fair is related to more frequent informative engagement (.169) and is not significantly related to general engagement. Respondents with a more positive perception of scientists tend to engage more in cultural science activities (.236) but less in its general form (-.019), as is the case for those who prefer experts' lead in decision-making. Finally, being more optimistic towards the potential impact of science and technology on the future society is negatively related to informative engagement (-.036) and positively related to general engagement (.118). It can be noticed that all science attitudes are more strongly related to informative engagement, described by culture-enhancing activities typically related to curiosity and interest, and have minor or not significant relationship with general engagement, an overall form of engagement although more strongly described by activities aimed at influencing policy-making and science co-creation. Indeed, the effect of SES on this last form of engagement has not been markedly affected by the inclusion in the model of science attitudes. This result underlines the relevance of understanding engagement as multidimensional and provides further clues contrasting the double deficit narration (Dawson, 2014b) of the disengaged as disinterested when it comes to active science engagement.

Figure.2 Exploratory model results with fully standardized coefficients. The items composing the latent variables have been omitted for ease of display. All coefficients are significant at p≤.001, except between perception of scientists and general engagement (-.005), which is significant at p≤.01. Dashed lines indicate no statistically significant relationship. The bottom box shows the calculations for the indirect effects of socio-economic status through each of the mediating variables on both factors of engagement and the total effects, with standard errors in parentheses. The significance of the coefficients reflects those of the direct relationship.



Socio-economic status	Informative engagement	General engagement
Indirect effect through Techno. tolerance	.019 (.002)	-.010 (.001)
Indirect effect through Science interest	.109 (.004)	.055 (.001)
Indirect effect through Science fairness	.046 (.003)	.003n.s. (.001)
Indirect effect through Percept. of scientists	.067 (.003)	-.005 (.001)
Indirect effect through Technology optimism	-.003 (.001)	.011 (.001)
Total indirect effect	.237 (.007)	.054 (.003)
Total effect	.277 (.008)	.192 (.005)

5. Discussion and Conclusion

The results of this analysis provide insights into the relationship between socio-economic status and science engagement and investigate the mediating role of citizens' participation in decision-making and science attitudes. Drawing on social psychology literature and status legitimation theory, I hypothesized that individuals with more disadvantaged socio-economic status would rely more on official authorities and feel less invested in taking part in science decision-making and that this would translate into a lower general involvement with science activities. The present results highlight that this is only partially the case. Individuals with a more advantaged socio-economic situation are more in contact with science, both in an informative and a general form than their more disadvantaged counterparts (*Hypothesis 1*, confirmed). However, at the same time, they also tend to favor more experts' involvement in science decision-making (*Hypothesis 2*, rejected). Additionally, favoring experts' lead is positively related to engagement through cultural-enhancing activities and negatively related to general active engagement, although the size of this effect is small (*Hypothesis 3*, partially confirmed). The indirect effects of socio-economic status through technocratic tolerance follow this trend, but the sizes of the effects are not enough to support or refute the argument. This might be due to a substantial absence of a relationship between the proposed concepts, poor measurement issues, and a lack of distribution of responses across the items considered (shown in the Supplemental Materials section 3).

Looking at the substance of the relationship, system legitimation theory does not seem to receive full support when applied to public engagement with science. Reliance on experts for decision-making about science issues does not seem to be among the reasons for lower engagement among people from less advantaged socio-economic strata of society. Instead, despite the lower engagement, they seem to indicate a preference for less exclusive participation of experts in science decision-making. Viewing these results from a framework of institutional alienation (Gauchat, 2011), disadvantaged members of society might perceive experts as members of the elite that they feel alienated from and are thus less inclined to leave deliberative power in their hands. Indeed, looking at the association between SES and the perception of scientists, this interpretation seems plausible. This could be indicative of a schism between the performed and preferred levels of engagement with science or of the fact that the two concepts respond to two different lines of reasoning and are weakly related, as it has been at times observed in political research (Bowler et al., 2007). Having a view on the appropriate actors for science decision-making or on the importance of public opinion may not be related to how individuals approach science in their daily lives. The former assumption was investigated and conceptualized as *a democratic deficit* in a study by Mejlgaard and Stares (2013) across European countries. Respondents living in countries with long traditions of citizen deliberation varied in their preferred level of public involvement in decision-making and preferred informative engagement to policy-influencing activities. At the same time, those respondents living in countries lacking participatory infrastructure are more prone to favor public participation in science decision-making but then engage very little. The present study's results might indicate that a similar pattern could be found across socio-economic groups in society, with the more disadvantaged preferring greater participation but not achieving it. Further research could build on these results and explore the extent to which social structure acts as an enabler or deterrent of individual inclinations and can shape the way in which individuals relate to scientific topics. Moreover, when it comes to deliberative (science) engagement, it has been observed that members of the public welcome more participative settings in which they perceive that their input is active and valued, rather than where they just receive science updates or the dialogues don't have a tangible outcome (Dreyer et al., 2021). Indeed, thoughtfully incorporating the public into deliberative dialogues may allow contributions from traditionally excluded population groups, promoting positive social change (Chen, 2021). All this leads to the consideration that, at least in the case of deliberative engagement, the presence and the effectiveness of receptive participation infrastructure is a fundamental requirement for science engagement to be carried out in a satisfactory way for institutions and citizens. Much of the focus of the literature on public engagement with science focuses on understanding individuals' personal motives and barriers, whereas little space has been given to evaluating the structures that generate these motives and should enable engagement (Reynolds et al., 2022). Thus, an impactful and relevant research direction would be exploring how social and institutional settings act together in favoring or limiting citizens' interaction with scientific knowledge, and its production and governance.

The exploratory analyses included in the second part of this study relate to the second speculative assumption put forward and try to test whether other science attitudes are related to engagement. Higher socio-economic status is associated with overall more positive attitudes towards science, with more interest, the perception that science is socially fair, a more positive idea of scientists' abilities, and a slightly more optimistic view of science and technology's impact on society. However, as for technocratic tolerance, most of the effects are rather small when it comes to the relationship of these attitudes to science engagement. Interest in science is the main factor associated with engagement, especially the informative kind. Being more interested in scientific developments is positively associated with both kinds of engagement, although more strongly with science activities that tackle curiosity and are aimed at acquiring information or being entertained (going to museums, watching documentaries, etc.). This finding highlights the substantial importance of considering the multidimensionality of engagement for its complete understanding. Indeed, not only science interest but all the science attitudes considered here relate far less strongly to general engagement. This includes activities directed at influencing science decision-making or production, and their inclusion still leaves a substantial amount of its relationship with SES unexplained, which is not the case for informative engagement. Furthermore, the fact that interest, as other science attitudes more or less related to engagement, is predicted by socio-economic status might be a remark of the existence of structural inequalities when it comes to people's relationship with science (Dawson, 2018, Godec et al., 2018). If the idea of science capital (Archer et al., 2015) holds, then different reasons behind various levels of science engagement and science attitudes could be imagined for different social groups. Studies exist on the characteristics and attitudes of participants of various science-related activities such as science festivals and citizen science (e.g., Rose et al., 2017; Jensen & Buckley, 2014; Füchslin et al., 2019), online science content (Hargittai et al., 2018; Rosenthal, 2018; Hu et al., 2022), or deliberative projects (Dreyer et al., 2021; Liu et al., 2022). However, more work could be done to enrich our understanding of why and how people from more disadvantaged social strata engage or not with science. It might be the case that the way in which engagement with science has been conceptualized and investigated in Public Understanding of Science scholarship does not reflect its stratified and varied reality (in the meaning of Chilvers and Kearnes, 2020). A valuable future research output would be to understand if this is the case and elaborate instruments to measure this concept in a socially just way that reflects everyone's reality.

To conclude, this study poses more questions and opens new research directions than the answers it provides. This is due to the nature and depth of the available data but also to the fact that studies aimed at understanding the effect of social structure on public engagement with science still represent a minority in the landscape of science communication and public understanding of science. The present results add to the existing evidence on the impact of social circumstances and the state of life on the relationship between science and the public. Social structure matters, which has consequences for how people relate to science and the methodological choices to approach this relationship.

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Data

Special Eurobarometer 561: *European citizens' knowledge and attitudes towards science and technology.* European Commission, Brussels (2022) Eurobarometer 95.2 (2021). *GESIS, Cologne. ZA7782 Data file Version 1.0.0, https://doi.org/10.4232/1.13884.*
Data file and related documents (questionnaire) are also retrievable at:
https://data.europa.eu/data/datasets/s2237_95_2_516_eng?locale=en

Socio-economic status and authority deference.
Understanding science (dis)engagement in Europe.

Supplemental material

Content

Main Analysis

1. Science Engagement

a. Descriptive Statistics Table

	mean	st. dev.	min	max	skewness	kurtosis
Informative engagement						
a. Talk with friends about science	2,55	1,00	1	4	-0,29	-1,01
b. Watch docum. / Read science	2,68	1,02	1	4	-0,42	-0,93
c. Visit museums	2,07	0,93	1	4	0,26	-1,09
d. b Study science in free time	1,81	0,94	1	4	0,82	-0,50
Science Governance						
e. Sign petitions / Join demonstrations	1,73	0,92	1	4	0,93	-0,35
f. Attend public meetings	1,57	0,81	1	4	1,26	0,67
g. Participate in non-gov activities	1,47	0,78	1	4	1,58	1,63
h. Contact public authorities	1,41	0,73	1	4	1,79	2,46
Co-creative engagement						
i. Provide personal data for research	1,85	0,97	1	4	0,69	-0,86
j. Participate in science projects	1,53	0,85	1	4	1,46	1,05
k. Take part in clinical trials	1,50	0,82	1	4	1,47	1,05
l. Lend computer to research	1,37	0,73	1	4	1,99	3,14

Q14 in the questionnaire, respondents are asked how often they perform each of the activities listed. Answer categories of the recoded items go from 1=Never to 4=Regularly. The items have been elaborated as indicators of three theoretical forms of science engagement. The first four describe an information-oriented type of engagement; the second four represent engagement aimed at influencing science governance; the last four are examples of co-creative engagement. In the table, items are displayed according to this division.

b. Comparison of Fit Indices

In order to establish the best way to operationalize science engagement I have followed the procedure shown by Ben-Elyahu and colleagues (2018)[4] in a study about the dimensionality of students' engagement. They used confirmatory factor analysis (CFA) to be able to understand the underlying structure of the engagement scale by showing the underlying latent factors and the relationship between items and indicators. Different structure configurations are assessed and compared in order to select the best fitting model that better represents the natural structure of the data. Applying this procedure, I have tested the fit of various configurations: a *unidimensional* model, operationalizing engagement as a unique factor of all items (as stated in the pre-registration); two *multidimensional* models, one following the theoretical categorization explained

[4] Ben-Eliyahu, A., Moore, D., Dorph, R., & Schunn, C. D. (2018). Investigating the multidimensionality of engagement: Affective, behavioral, and cognitive engagement across science activities and contexts. *Contemporary Educational Psychology*, *53*, 87-105.

above and one following a horizontal/vertical engagement[5] division (informative and governance+co-creative); two *bifactor* models following the same categorizations. However, the first bifactorial model estimating three engagement factors defined by theory only runs if "take part in clinical trial" is deleted from the analysis, the results shown in the table below belong to this model. This might suggest that the corresponding latent factor does not exist, therefore the adjusted model estimates informative engagement and governance-oriented engagement, and then an overall factor including all twelve items. This model fits quite well, but the factor loadings for the governance engagement are higher in the overall factor than in the single one, signaling that the single governance factor might not be appropriate. The second bifactor model including informative engagement and the sum of governance and co-creative along with the overall factor presents rather low loadings on the second factor (governance+co-creative). As for the previous model, this might suggest that the second factor is not appropriate, therefore the adjustment model estimates only informative engagement and an overall factor.

For all these reasons, the last formulation is the model of choice. Despite the model fit is not the best among all those estimated (although still excellent), the substantial interpretation is. All models were estimated using Weighted Least Square Maximum Variance estimator, listwise deletion and no correlated disturbances. In structural model, I have fitted the following correlated disturbances for the two engagement factors (find correspondence between letters and items in the previous table): c and d, f and g-i-j, g and h-i, h and i, j and k, k and l. Correlating all the items disturbances would lead the model to not converge, therefore the correlations have been chosen by following the suggestions from the Modification Indexes.

Model	Chi-Square	df	CFI	TLI	RMSEA	SRMR
Unidimensional	39311.614	54	0.963	0.955	0.142	0.080
Multidimensional 3cat	20712.048	51	0.982	0.977	0.060	0.055
Multidimensional 2cat	21650.461	53	0.981	0.976	0.062	0.058
Bifactor 3cat (-clin trial)	40956.794	33	0.914	0.868	0.146	0.130
Bifactor 3cat adjusted	10256.585	46	0.992	0.988	0.044	0.040
Bifactor 2cat (negat. load)	7969.717	42	0.995	0.991	0.072	0.033
Bifactor 2cat adjusted	12117.473	50	0.990	0.987	0.047	0.044

[5] Mejlgaard, Niels and Stares, Sally (2013) Performed and preferred participation in science and technology across Europe: exploring an alternative idea of 'democratic deficit'. Public Understanding of Science, 22 (6). pp. 660-673.

2. Socio-Economic Status

a. Descriptive Statistics Table

	mean	st. dev.	median	min	max	skewness	kurtosis
Education	20,60	5,63	19	1	90	1,99	12,40
Parents' education	3,28	1,13	3	1	6	0,20	-0,42
Job Prestige	6,14	2,61	7	1	9	-0,49	-0,94
Self-reported social level	2,59	0,94	3	1	5	-0,39	-0,49
SES additive index standardized, group centered	0	0,61	0	-2,49	3,68	0,03	0,12
Discarded indicators							
Difficulties in paying bills	2,60	0,61	3	1	3	-1,30	0,57

Education, D8 in the questionnaire, has been asked as the age of respondents at the end of full-time education. The resulting variable included in the questionnaire is shown in the table as "Education", it ranges from 0 (no full-time education) to 90 and is unsurprisingly severely peaked (see kurtosis). The answer categories included "still studying" and these respondents have been assigned the average education value in their age category. No education is the minimum value (1) and don't know and refusal have been coded as missing.

Parents' education has been constructed by taking the maximum variable of father's and mother's education (D92 a and b in the questionnaire). Respondents were asked to indicate the maximum educational level of their father and mother by choosing from: "not completed primary", "completed primary", "completed secondary", "completed post-secondary vocational studies, or higher education to bachelor level or equivalent", "completed upper level of education to post-graduate or master's degree or equivalent", "completed doctoral degree or equivalent".

Job prestige has been recoded according to the EGP[6] schema and can be seen in the following subsection.

Self-reported social level, D63 in the questionnaire, asks respondents "Do you see yourself and your household belonging to…?" and to choose among: "the working class of society", "the lower middle class", "the middle class", "the upper middle class", "the higher class". This variable was used in the building of the latent variable Socio-Economic Status instead of Difficulties in paying bills, D60 in the questionnaire, which is shown in the table. Respondents were asked to report if in the previous 12 months they had difficulties paying their bills "most of the time", "from time to time" and "almost never/never". This objective measure of economic capital shows a rather skewed distribution (see skewness for the discarded indicator). Moreover, recent studies report that subjective measures of economic situation seem to perform better when assessing people's attitudes towards science[7]. Although none of the two measures included in the Eurobarometer can be considered perfectly objective, as reporting the household's income would be, the one investigating respondents' difficulties in paying bills more closely approximates it and the self-reported social level can be

[6] Erikson, R., Goldthorpe, J. H., & Portocarero, L. (1979). Intergenerational class mobility in three Western European societies: England, France and Sweden. *The British Journal of Sociology*, *30*(4), 415-441.
[7] Fuglsang, S. (2022, October 29). Is science for the rich and powerful? Investigating the relation between income and trust in science across 145 countries. https://doi.org/10.31235/osf.io/89bn4. Preprint.

considered as subjective. For these reasons, I have decided to deviate from what stated in the preregistration and use self-reported social level as measure of economic capital in this study.

b. Mapping of Job prestige according to EGP schema

EGP Classification from: Ganzeboom, H. B., & Treiman, D. J. (2003). Three internationally standardised measures for comparative research on occupational status. In Advances in cross-national comparison (pp. 159-193). Springer, Boston, MA.	
Higher Managerial and Professional Workers	1
Lower Managerial and Professional Workers	2
Routine Clerical Work	3
Routine Service and Sales Work	4
Small Self-Employed with Employees	5
Small Self-Employed without Employees	6
Manual Supervisors	7
Skilled Manual Workers	8
Semi- and Unskilled Manual Workers	9
Agricultural Labour	10
Self-Employed Farmers	11

Eurobarometer Categories
Self-employed farmer
Self-employed fisherman
Self-employed professional (lawyer, medical practitioner, accountant, architect, etc.)
Owner of a shop, craftsmen, other self-employed person
Business proprietors, owner (full or partner) of a company
Employed professional (employed doctor, lawyer, accountant, architect)
Employed position, general management, director or top management (managing directors, director general, other director)
Employed position, middle management, other management (department head, junior manager, teacher, technician)
Employed position, working mainly at a desk
Employed position, not at a desk but travelling (salesmen, driver, etc.)
Employed position, not at a desk, but in a service job (hospital, restaurant, police, fireman, etc.)
Employed position, supervisor
Employed position, skilled manual worker
Other employed (unskilled) manual worker, servant
Never did any paid work
Responsible for ordinary shopping and looking after the home, or without any current occupation, not working
Student
Unemployed or temporarily not working
Retired or unable to work through illness

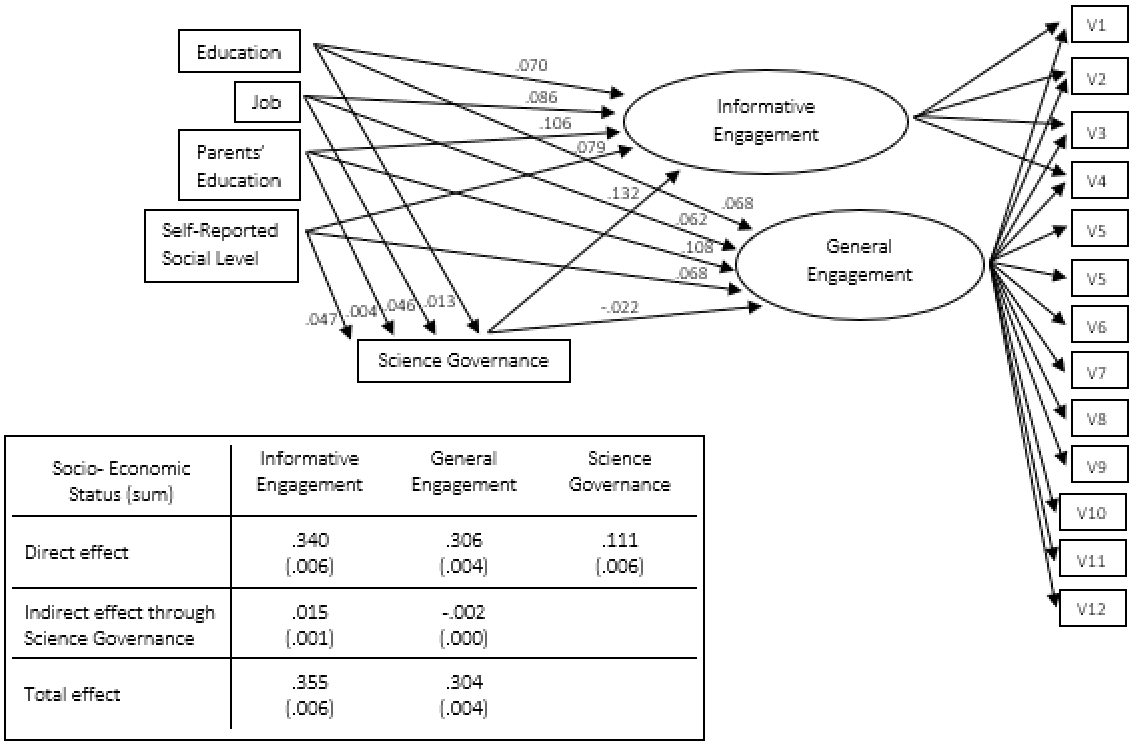
Eurobarometer Categories	**EGP code**	**EGP Label**	**New Code**
Self-employed farmer	11	Self-Employed Farmers	8
Self-employed fisherman	11	Self-Employed Farmers	8

Self-employed professional (lawyer, medical practitioner, accountant, architect, etc.)	1	Higher Managerial and Professional Workers	1
Owner of a shop, craftsmen, other self-employed person	2	Lower Managerial and Professional Workers	2
Business proprietors, owner (full or partner) of a company	1	Higher Managerial and Professional Workers	1
Employed professional (employed doctor, lawyer, accountant, architect)	1	Higher Managerial and Professional Workers	1
Employed position, general management, director or top management (managing directors, director general, other director)	1	Higher Managerial and Professional Workers	1
Employed position, middle management, other management (department head, junior manager, teacher, technician)	1	Higher Managerial and Professional Workers	1
Employed position, working mainly at a desk	3	Routine Clerical Work	3
Employed position, not at a desk but travelling (salesmen, driver, etc.)	4	Routine Service and Sales Work	4
Employed position, not at a desk, but in a service job (hospital, restaurant, police, fireman, etc.)	4	Routine Service and Sales Work	4
Employed position, supervisor	7	Manual Supervisors	5
Employed position, skilled manual worker	8	Skilled Manual Workers	6
Other employed (unskilled) manual worker, servant	9	Semi- and Unskilled Manual Workers	7
Never did any paid work			9
Responsible for ordinary shopping and looking after the home, or without any current occupation, not working	When possible mapped according to the last occupation, otherwise in "Never had any paid work"		
Student			
Unemployed or temporarily not working			
Retired or unable to work through illness			

Recoded Variable - EGP		N (in dataset)	From Last Occupation	Tot
1	Higher Managerial and Professional Workers	7682	4073	11755
2	Lower Managerial and Professional Workers	899	399	1298
3	Routine Clerical Work	3944	1851	5795
4	Routine Service and Sales Work	3188	2100	5288
5	Manual Supervisors	549	354	903
6	Skilled Manual Workers	3198	2294	5492
7	Semi- and Unskilled Manual Workers	1009	1682	2691
8	Self-Employed Farmers	446	413	859
9	Never did any paid work		3016	3016
				37097

c. Alternative Analysis

Including SES items singularly



Socio- Economic Status (sum)	Informative Engagement	General Engagement	Science Governance
Direct effect	.340 (.006)	.306 (.004)	.111 (.006)
Indirect effect through Science Governance	.015 (.001)	-.002 (.000)	
Total effect	.355 (.006)	.304 (.004)	

CFI: 0.990; TLI: 0.986; RMSEA: 0.032; SRMR:0.027. Estimator: WLSMV. Robust estimates. Standardized coefficients.

3. Science Governance

a. Descriptive Statistics Table

	mean	st. dev.	median	min	max	skew	kurtosis
Appropriate level of public involvement	2,65	0,72	3	1	4	-0,44	0,05
Decision should be based on experts/people	1,75	0,43	2	1	2	-1,17	-0,64
Additive Index	2,95	0,80	3.5	1	4	-0,97	-0,25

Appropriate level of public involvement. Q7 in the questionnaire, asking respondents “What level of public involvement do you think is appropriate when it comes to decisions about science and technology?”. Answer categories of the recoded variable are: “Public opinion should be the main concern”, “The public should be consulted, and public opinion seriously considered”, “Decisions should be made by scientists, engineers and politicians, but the public should always be informed”, “The public does not need to be involved”.

Decision should be based on experts/people. Q13a in the questionnaire, asking respondents to select the option closest to their point of view. Answer categories are: “Decisions about science and technology should be based mainly on what the majority of people in a country think” and “Decisions about science and technology should be based mainly on the advice of experts”.

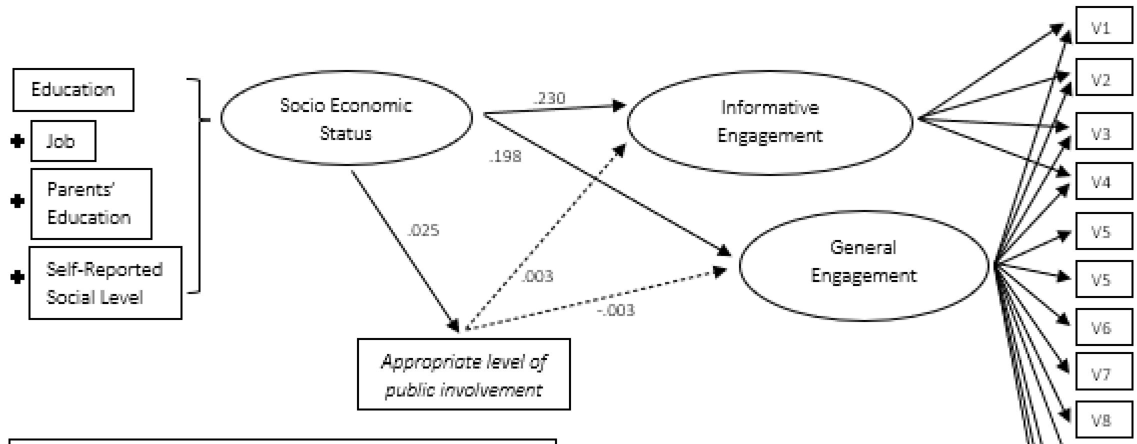
To build the additive index, the dummy variable has been coded as 1 and 4, as these answer options align with the most extreme values (1 and 4) of the categorical variable.

b. Crosstabulation of the two items

	Decisions based the majority of people	*Decisions based the advice of experts*
Public opinion should be the main concern	1185	1242
The public should be consulted	3547	7220
The public should be informed	3637	16911
The public does not need to be involved	672	2131

c. Alternative Analyses

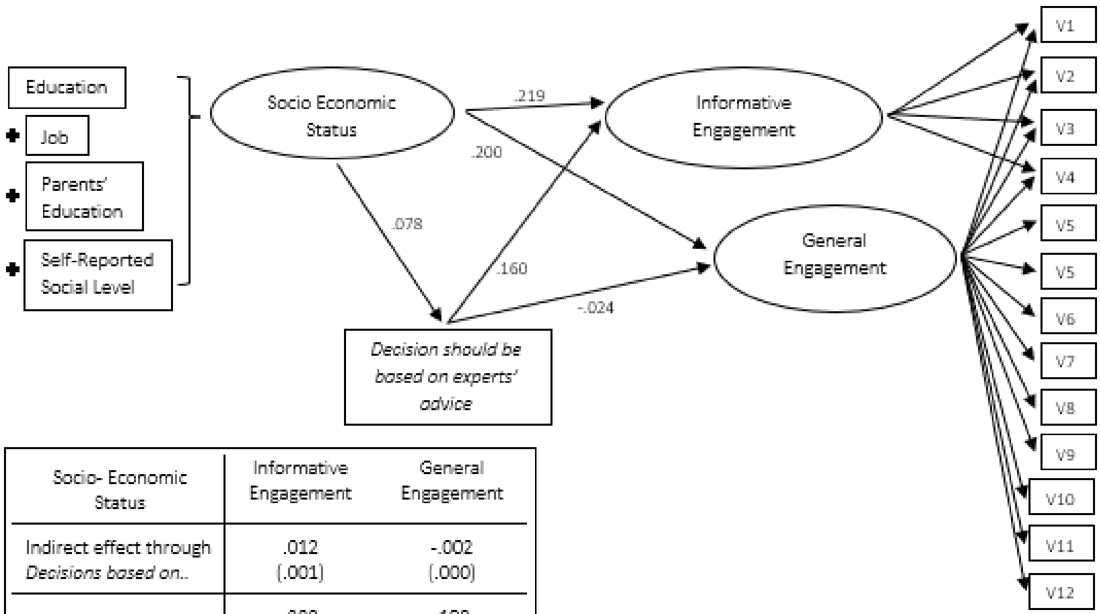
- Including only *Appropriate level of public involvement*



Socio- Economic Status	Informative Engagement	General Engagement
Indirect effect through *Public Involvement*	-.000 (ns) (.000)	-.000 (ns) (.000)
Total effect	.230 (.002)	.198 (.001)

CFI: 0.991; TLI: 0.987; RMSEA: 0.035; SRMR:0.029. Estimator: WLSMV. Robust estimates. Standardized coefficients.

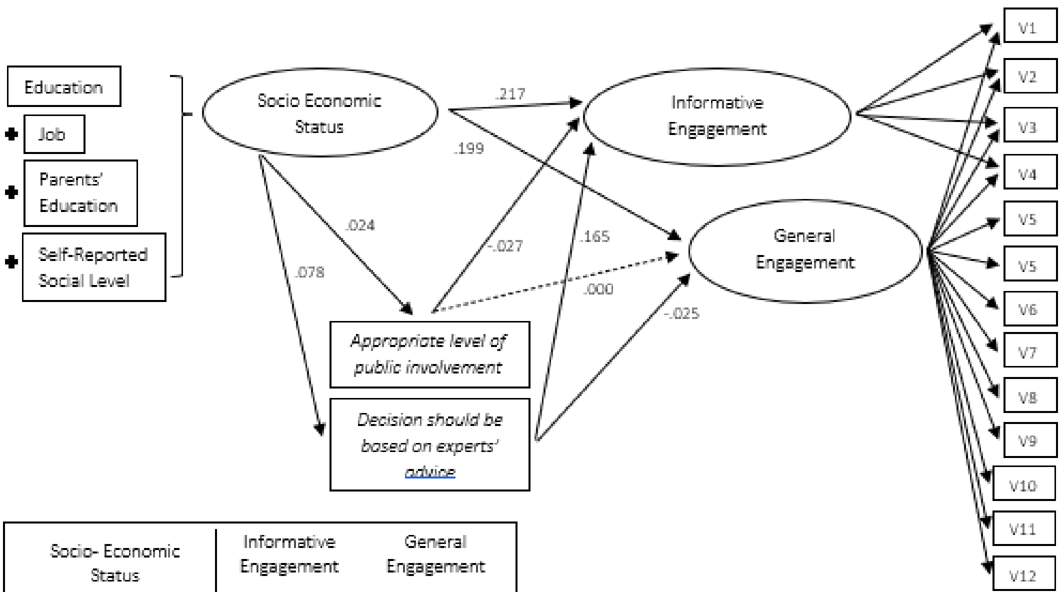
- Including only *Decision should be based on experts/people*



Socio- Economic Status	Informative Engagement	General Engagement
Indirect effect through *Decisions based on..*	.012 (.001)	-.002 (.000)
Total effect	.232 (.007)	.199 (.004)

CFI: 0.990; TLI: 0.986; RMSEA: 0.036; SRMR:0.030. Estimator: WLSMV. Robust estimates. Standardized coefficients.

- Including both indicators singularly



Socio- Economic Status	Informative Engagement	General Engagement
Indirect effect through both items *(sum)*	.012 (.001)	-.002 (.000)
Total effect	.229 (.007)	.197 (.004)

CFI: 0.990; TLI: 0.986; RMSEA: 0.035; SRMR:0.029. Estimator: WLSMV. Robust estimates. Stand. Coefficients.

4. Control Variables

a. Descriptive Statistics Table

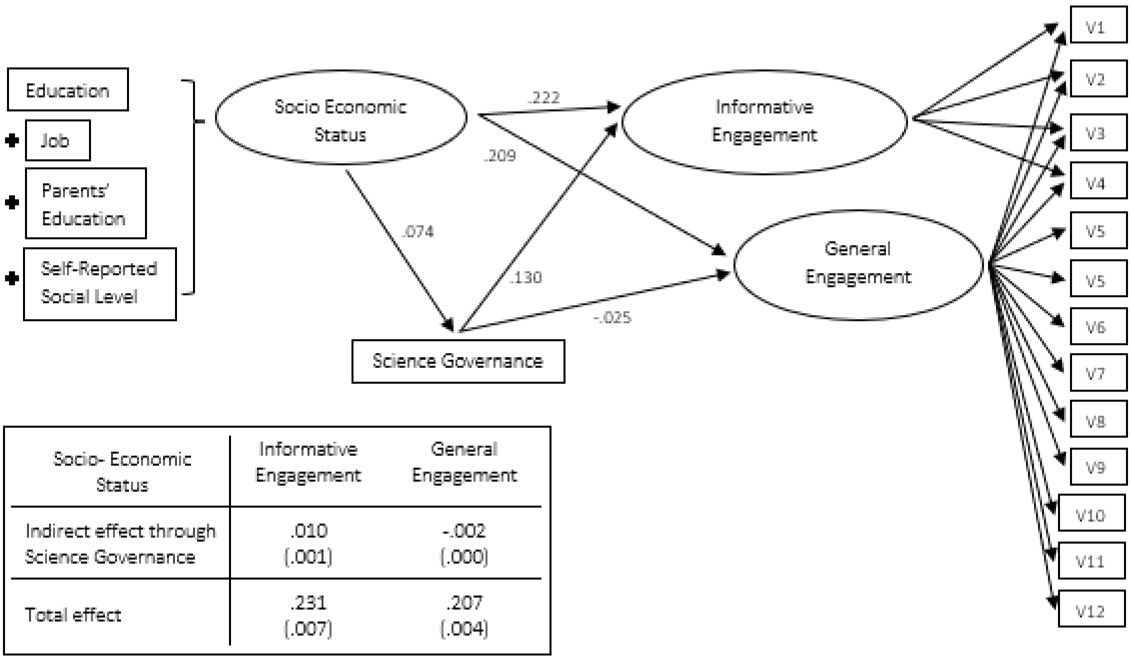
	mean	st. dev.	median	min	max	skew	kurtosis
Gender (1=female)	0,52	0,50	1	0	1	-0,08	-1,99
Age	3,80	1,64	4	1	6	-0,18	-1,16

Gender, D10 in the questionnaire, is a dummy variable in which 0 is "male" and 1 is "female".

Age, D11 in the questionnaire, as a continuous variable is not available in the dataset, therefore I have used its categorical version (employing it as continuous): 1 is "15-24", 2 is "25-34", 3 is "35-44", 4 is "45-54", 5 is "55-64", 6 is "65+".

I have decided to leave out of the analysis left-right scale, closeness to science and science literacy as these can be considered attitudes, either political or science-related, and it does not seem correct to predict an attitude with another attitude. Moreover, closeness to science and science literacy correlate moderately with the items used to operationalize Socio-Economic Scale (around 0.20).

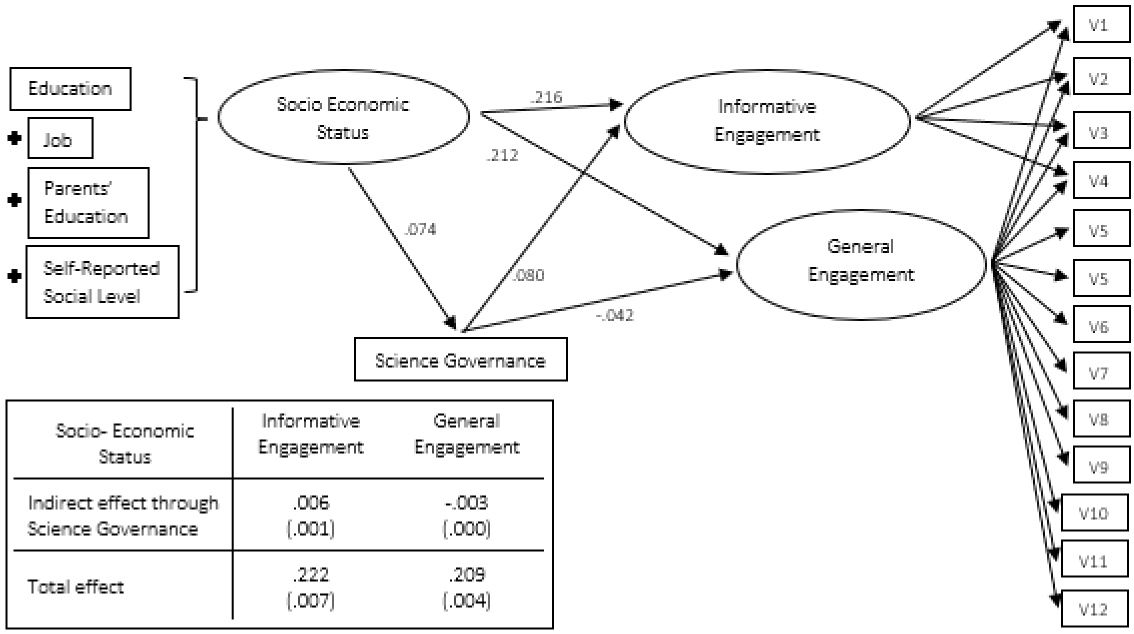
b. Analysis model without controls



Socio- Economic Status	Informative Engagement	General Engagement
Indirect effect through Science Governance	.010 (.001)	-.002 (.000)
Total effect	.231 (.007)	.207 (.004)

CFI: 0.993; TLI: 0.990; RMSEA: 0.035; SRMR:0.030. Estimator: WLSMV. Robust estimates. Standardized coefficients.

5. Structural Model with Fixed Effects (country dummies)



Socio- Economic Status	Informative Engagement	General Engagement
Indirect effect through Science Governance	.006 (.001)	-.003 (.000)
Total effect	.222 (.007)	.209 (.004)

CFI: 0.907; TLI: 0.877; RMSEA: 0.038; SRMR:0.017. Robust estimates. Estimator: MLR. Standardized coefficients. Reference country: United Kingdom.

Exploratory Analysis

6. Descriptive Statistics Tables

a. Science Interest

	mean	st. dev.	min	max	skew	kurtosis
Int in medical discoveries	2,23	0,66	1	3	-0,29	-0,78
Int. in science and technology discoveries	2,19	0,68	1	3	-0,25	-0,85
Int. in environmental problems	2,26	0,66	1	3	-0,33	-0,75

These three indicators of interest have been employed to measure general interest in science as they tackle various areas of science. Respondents have been asked, Q2 in the questionnaire, how interested they felt in each of the items, choosing from 1 “Not at all interested”, 2 “Moderately interested”, 3 “Very interested”.

b. Perception of Science Fairness

	mean	st. dev.	min	max	skew	kurtosis
Sci.&Tech. do not benefit people like you	3,49	1,20	1	5	-0,44	-0,75
Sci.&Tech. mostly improve lives of already better off people	2,50	1,11	1	5	0,50	-0,51
Sci.&Tech. mostly improve lives of already better off countries	2,20	1,00	1	5	0,78	0,23
Sci.&Tech. mostly help companies make money	2,28	1,05	1	5	0,62	-0,23

Perception of science fairness has been measured through these items included in a wider battery, Q17 in the questionnaire, asking respondents how strongly they agreed or disagreed with each of the statements. The answer categories go from 1 “strongly agree” to 5 “strongly disagree” where 3 is “neither agree nor disagree”. Higher values correspond to a perception of science as fairer and more equitable.

c. Perception of Scientists

	mean	st. dev.	min	max	skew	kurtosis
We can no longer trust scientists because they depend more and more on money from industry	2,59	1,08	1	5	0,33	-0,58
Scientists only look at very specific issues and do not consider problems from a wider perspective	2,71	1,06	1	5	0,24	-0,61
Nowadays problems are so complex that scientists are no longer able to understand them	3,13	1,14	1	5	-0,11	-0,84

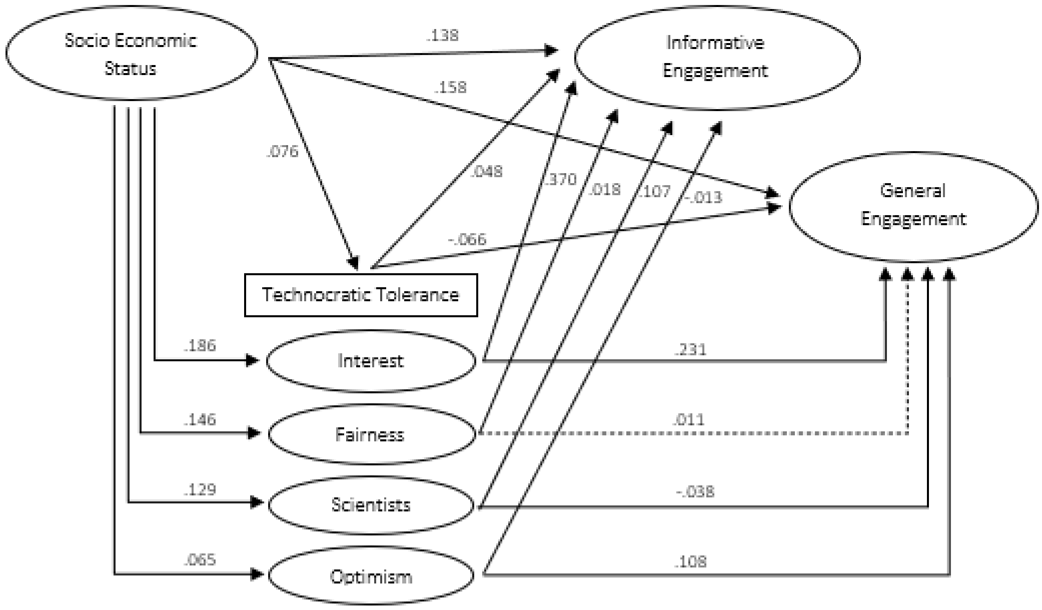
Perception of scientists and their authority has been measured by asking respondents how strongly they agreed or disagreed with each of the statements. The answer categories go from 1 “strongly agree” to 5 “strongly disagree” where 3 is “neither agree nor disagree”. Higher values correspond to a perception of scientists as more capable and trustworthy.

d. Technology optimism

	mean	st. dev.	min	max	skew	kurtosis
Science and technology make our lives easier, healthier and more comfortable	3,66	0,96	1	5	-0,60	0,07
Science prepares the younger generation to act as well-informed citizens	3,69	1,00	1	5	-0,62	-0,05
Thanks to scientific and technological advances, the Earth's natural resources will be inexhaustible	2,70	1,23	1	5	0,20	-1,00
Thanks to science and technology, there will be more opportunities for future generations	3,82	0,97	1	5	-0,79	0,35
Artificial intelligence and automation will create more jobs than they will eliminate	2,84	1,16	1	5	0,11	-0,83

Technology optimism has been measured by asking respondents how strongly they agreed or disagreed with each of the statements. The answer categories go from 1 "strongly agree" to 5 "strongly disagree" where 3 is "neither agree nor disagree". Higher values correspond to a more positive perception of science and technology future impact on society.

7. Structural model with fixed effects (country dummies)



Socio- Economic Status	Informative Engagement	General Engagement
Indirect effect through Techno. Tolerance	.004 (.001)	-.005 (.000)
Indirect effect through Science Interest	.069 (.003)	.043 (.001)
Indirect effect through Science Fairness	.003 (.001)	.002n.s. (.001)
Indirect effect through Percept. of Scientists	.014 (.001)	-.005 (.001)
Indirect effect through Technology Optimism	-.001 (.001)	.007 (.001)
Total Indirect effect	.088 (.007)	.042 (.003)
Total effect	.226 (.007)	.200 (.004)

CFI: 0.877; TLI: 0.800; RMSEA: 0.044; SRMR:0.021. Robust estimates. Estimator: MLR. Standardized coefficients. Reference country: United Kingdom.

Chapter 6
Article C

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Beyond deliberation. Exploring perceptions and experiences of science (dis)engagement in England.

Lucilla Losi

Abstract: This study explores alternative forms of public engagement with science through 25 semi-structured interviews with England-based participants from demographic groups with low levels of engagement. When considering established ways to engage with science, informants do not identify themselves as engaged and provide pragmatic reasons for their disengagement. However, as they elaborate on their personal experiences with science, they realize that science is more woven into their lives than initially acknowledged. The results underscore the pivotal role of personal perceptions and experiences in shaping science engagement, emphasizing the interplay between these perceptions and science institutions and challenging the conventional framework.

Keywords: science engagement, deliberation, disengagement, informal participation, science communication

1. Introduction

Public engagement with science is a key element in forming the relationship between science and society. Its definition varies and its practice includes a wide range of activities (Weingart et al., 2021) serving different levels of public involvement (Arnstein, 1969). In the academic literature, the relevance of mitigating the gap between science and the public has long been interrogated (Stilgoe et al., 2014) together with the potential benefits for both scientific process and citizens (Stirling, 2008). Underlying much of the literature on science engagement is the assumption that the most beneficial way for the public to engage with science is taking part in deliberative activities that can contribute to policy making or scientific development (Schrögel & Kolleck, 2019). Indeed, the assumption that every person should be equipped with tools and opportunities to take part in modern societies has long been at the core of systematic reflections on the science-society relationship (e.g. The Royal Society, 1985). This perspective highlights the important democratic role of deliberative public engagement with science, addressing public support for science or better policy making (Priest, 2018; Davies, 2022). Consequently, current research has primarily focused on public engagement according to this assumption by elaborating ways to include the public in more effective (Chen, 2021), or inclusive (Kano et al., 2019) ways. Building equal, deliberative processes is fundamental for just democratic societies, however it represents only one of various ways of conceptualizing engagement (Schrögel & Kolleck, 2019). This selective attention of the academic literature contributes to labelling everything that falls outside of conventional perceptions of deliberation as *disengagement*, as opposed to studying in greater detail how *the disengaged* encounter and interact with science and scientific concepts. Without undermining the importance of this core feature of democracy, the present study offers an analysis focused on the publics' own interpretation of science engagement, rather than on a pre-defined set of practices of science that they might feel alienated from.

The scope of deliberative democracies and the goals of scientific citizenship have long been debated in science and civic engagement literature. Considered as a leading condition to achieve consensus and rational policy results (Habermas, 1975; Cohen, 2009), the concept of deliberative democracy hinges on positioning (informed) citizens at the core of debates and decision-making. Following this framework, the notion of *scientific citizenship* has been introduced to describe the active role in understanding and shaping science that citizens are expected to have in contemporary knowledge societies (Mejlgaard, 2009). Accordingly, the activities included in the definition of scientific citizenship have traditionally been civic or, more recently, co-creative in nature. This concept has been central in the last two decades for imagining and interpreting changes in contemporary societies, and it still provides the basis for effective participatory models (e.g. Chen, 2021).

In a book chapter inspired by fieldwork among Maker Spaces in the United States, Davies (2015) builds on the theoretical shift from deliberative processes to deliberative societies (i.e. Mansbridge et al., 2012) to argue for the value of considering "scientific citizenship as something that is spread through society […] beyond the categories of invited and non-invited participation" (Davies, 2015:173). In the concluding remarks, the author calls for a reflection on the implications that this perspective on engagement, which essentially broadens the notion of who scientific citizens are, could have for the practice and the research in this field. Almost ten years later, this take on public engagement seems more relevant among researchers and practitioners of public engagement, although the general framework is advancing slowly (for an overview, see: Weingart & Joubert, 2019).

Considering the prevalent conceptualization of engagement, as already highlighted by Dawson (2018), a substantial body of research has been focusing predominantly on comprehending the behavior and preferences of the engaged publics. Examples are studies of reasons and gains of participating in science festivals (e.g. Jensen & Buckley, 2014; Rose et al., 2017; Jensen et al., 2021) or citizen science activities (Edwards et al., 2018; Paleco et al., 2021). These studies, while offering valuable contributions for understanding the mechanisms of engagement, have left a gap in our understanding of the disengaged population, which is generally the largest segment of the population (Losi, 2023). Moreover, it has been repeatedly observed that the audience of formal science communication initiatives is primarily composed of educated males from local ethnic majorities (Archer et al., 2015; Jensen et al., 2021; Paleco et al., 2021) while people presenting a disadvantaged socio-demographic profile are generally disengaged and receive little further investigation. Previous research indicates that those social groups that are considered "excluded" from science tend to restrain from deliberative activities and predominantly engage in an informational manner (e.g. Dawson, 2018), however what this entails is still underdeveloped. While inequality in deliberative participation remains a significant concern, exploring broader or alternative forms of science engagement of people at the margins may widen the outreach possibilities of science communication and expand avenues for deliberation. Indeed, unconventional engagement can represent and develop into deliberative participation (Stofer et al., 2019; Bherer et al., 2023) and studying it can contribute to understanding the (dis)engagement among disadvantaged communities.

Reasons for (dis)engagement have often been sought among the population itself (e.g. Dryer et al., 2021), but a recent shift emphasizes the lack of inclusivity of science institutions in keeping members of marginalized populations from engaging with science (Dawson, 2018; Godec et al., 2022). This highlights the relevance of understanding the publics' relationship with science that goes beyond top-down defined activities and of discussing what constitutes relevant engagement and problematic disengagement. This article contributes to this ongoing debate by investigating how members of the public reflect on science engagement and what elements of their daily lives they recognize as such. To do so, the following two research questions will guide the analysis: RQ1. What are participants' rationales behind (dis)engagement with science? RQ2. How do they perceive, experience, and recognize science in everyday life?

2. Methods

This study is based on 25 face-to-face semi-structured interviews that took place between May and July 2023 in a medium-sized university town in England (UK). The United Kingdom has a long history of social hierarchies and this awareness emerged unprompted several times during the interviews. In a study about the role of personal perceptions and experiences of engagement, this generalized social awareness represents an interesting setting. The town's average population characteristics resemble those for England as a whole, with lower general income but comparable educational levels. The town hosts a large university, detached from the city center, and described as removed from the social fabric of the city by several participants.

Interviewees have been selected following a purposeful maximum-variation strategy (Patton, 2014, p. 264) aiming to obtain a diverse and informative group of participants that can help to understand the science-related characteristics of a loosely defined group of the population (people as non science-professionals). To be included in the study, participants had to be comfortable in expressing their thoughts in English language, adults (older than 18), not in education, not employed in high prestige or sciences-intensive jobs (managers, engineers, architects, medical doctors), not working as lecturers or researchers for a university or other research institutions and not having a member of the immediate family that does so. More broadly but of less relevance with regard to the exploratory objectives of the study, I aimed at achieving variety on age, gender, employment, and ethnic background. The demographic characteristics of each informant, identified with pseudonyms, can be found in the Supplementary Materials. Recruitment took place online through posting on various social media groups explicitly linked to the chosen location, offline through advertisements posted in various points of interest around town, and finally word of mouth among participants and their networks. Interviews took place in cafés, and have been conducted, audio-recorded, transcribed and analyzed by the author of this study. Upon completion of the interview each participant was given a 10£ voucher for grocery shopping. Offering payback to participants in qualitative studies is a debated practice (e.g. Head, 2009). I stand by the argument that the time and effort informants spend in providing researchers with material to undertake their job and advance their careers, besides science, should be regarded as working time and therefore compensated. Each interview lasted for about 50 minutes and an interview guide, which can be seen in the Supplementary Materials, guided each session while leaving space for the participants to diverge and freely contribute to the construction of the interview material. No boundaries were imposed on how science had to be understood, instead informants were encouraged to define it in their own terms.

Data was analyzed in NVivo following a two-step approach (Miles et al., 2018). In the first step, I created detailed open codes inductively to identify salient issues and relevant topics mentioned by the interviewees. In the second step, the resulting codes were selectively grouped, identifying relevant patterns and categories tackling the research questions. This second and final step is based on the open codes identified in the first stage of the analysis and complemented by guidance from existing empirical studies (e.g. Dawson, 2018, Kaskazi, 2023). A display of the code development is included in the Supplementary Materials.

3. Findings

In this section, I present the themes emerging from the analysis of the interviews. The first part focuses on informants' reflections regarding various forms of science engagement, while the second part describes the ways in which they describe engaging with science in their lives. The arguments are illustrated by quotes[8] from participants, who are be identified with a pseudonym, age, and employment status.

3.1 Science engagement "in theory"

For informants, expressing their considerations on the role of science in society and the relevance of public engagement was somewhat hard, suggesting that science and science engagement are not present in informants' everyday actions. To facilitate and guide their reflections, informants were asked to elaborate their thoughts on three key indicators of public engagement with science: activities aimed at the acquisition of scientific knowledge, involvement in policy making, and, more recently, science co-creation (Gaskell et al., 2006; Mejlgaard and Stares, 2013; Macq et al., 2020). These have been presented to the respondents as: being up to date with science developments, making their voice heard in government decision making on science-related issues and having the possibility to participate in shaping science content together with scientists. Thus, mentions of engagement or disengagement throughout this section refer to these three groups of activities.

Reflecting on these three ways of engaging with science, informants elaborate on both the reasons to engage and factors that keep them from doing so. Given the difficulties in assessing the value of science engagement, references to the benefits of engaging with science are mostly articulated around the general contribution that science has in one's personal life. The most frequently mentioned gain from the presence of science in daily life seems to be a better understanding of the world and an increased ability to make sense of it. As Sylvia (46, Homemaker) explains when asked about the role of science in society:

> I think it's to make people more aware of what's going on around them. I think it's pivotal to everything that everybody does, being more aware of the way that they interact with each other, with animals, with the planet, with plastic, with carbon. Science is, like, hugely important.

Another topic that emerges while discussing the importance of science in daily life is personal inspiration and representation. Some participants mention that specific scientists or scientific endeavors have served as models for them when growing up or addressing life hardships. Examples of this include Hannah (60, cleaner and ceramicist) who mentioned Maria Montessori as her personal idol for her stubbornness, perseverance and her being female without having to be "friendly, warm or fun".

However, despite recognizing the importance of being in contact with science, most informants do not recognize themselves as deeply engaged. Participants provided their reasons not to pursue science-related activities, which can be grouped according in 3 non-exclusive groups: those referring to personal deficits, those mentioning a lack of perceived relevance or efficacy of such activities and those highlighting external impediments.

3.1.1 Personal deficits

Reasons for disengagement associated with personal deficits refer to the informants' self-ascribed lack of knowledge, understanding or intelligence regarding science which discourages them from engaging with it. Science is often described as being far from the participants and not belonging to their universe, as Olivia (45, English and Math Teacher) for whom science is a "vast subject, so complicated" with "different levels of understanding" and that "feels beyond me in terms of a level of detail and understanding that is maybe

[8] The excerpts from the interviews are lightly edited in their grammar for clarity without affecting their meaning. Artifacts as "uhm" "yeah" have been omitted. […] indicates that some redundant text was cut for space reasons.

sometimes needed to understand some things". This is associated with a longing to be more knowledgeable, or with almost a sense of guilt for not knowing enough. At the same time, the perception of not being knowledgeable can be associated with a sense of fear of science, both conducive to retaining from engaging with scientific content. Jolene (69, Retired) exemplifies this reasoning:

> Even the very word scares me. I keep away from it. [laugh] If I thought that anything involved anything up a bit...then no, no! That's not for me. […] I don't have the skills. I don't think my brain functions that way. You know because I'm more practical. So… I do sort of leave it for people who know what they, or think they know what they're talking about. And then probably criticize them after when they've done it. [laugh]

Jolene is not alone in her desire to "leave" science to people that "know what they are talking about". The sense of lack of trust in one's own ability (or self-efficacy) to contribute with "anything that would be useful" (Shannon, 33, Mental Health Nurse) is often mentioned together with leaving science decision making in the hands of experts. When discussing the possibility for the public to be involved in science decision making and co-creation, informants struggled in picturing possible contributions of the general public. The difference between decision making over technical science aspects and over social aspects regarding science (Wynne, 2007, p.108) was only picked up by a couple of informants. Nevertheless, when participants sustaining this "deferent" (Howell et al., 2020) position describe the characteristics these experts should have, these are defined as "scientists" (Shannon, 33, Mental Health Nurse), or also people "who have worked in the field who have got experience in whatever the issue is" (Harriet, 38, Primary School Teacher). In a minority of cases these are "an activist or someone that has much more knowledge about science" (Scarlet, 55, Actor) or people from "all walks of life" capable of "sharing the views from a wider range of people" (Mildred, 40, Nurse Assistant).

3.1.2 Lack of relevance

Here are included reasons for disengagement that specifically relate to two types of science engagement activities: keeping up with science developments and having a say in government decision-making. Informants rationalize their scarce engagement with science content and updates by describing it as irrelevant to them. Keeping up to date with science is also described as overwhelming for "the amount of stuff you have to read" (Suzanne, 61, Administrative Staff), not very relevant for taking action as "we tend to get to know about developments once they've gone through loads of research already" (Scarlet, 55, Actor), or even pointless as "you can read about new ideas but it doesn't mean that it is actually going to happen" (Logan, 63, ex-Driving Instructor).

When it comes to engagement with government decision making on science-related issues, the perception of not being heard and lack of efficacy are the reasons most often brought forward for disengagement. "Being a realist, you've got more chance of them [*scientists*] listening to you than them [*government*]" says Evelyn (52, ex-Nursery Nurse) when reflecting on the importance of engaging in decision-making or science co-creation. Climate change and the environment are often mentioned to exemplify the perceived discrepancy between wills voiced by the population and actions taken by the government. As Sylvia (46, Homemaker), who considers virtual reality a "waste of technology" that "nobody asked for" and argues that, instead, the needed technology regards "alternative energy, anything that is going to help medically with people".

The social characteristics of the people that are "not being heard" by the government is also pointed out. Maeve (56, ex-Hairdresser) argues that "it's got to do with intention and also, I think um, because most of these people that are in government are privileged people […] I do feel that the less fortunate of people are not heard". Although emphasizing the privileged characteristics of the socioeconomic composition of the government, Mildred (40, Nurse Assistant) remarks the importance of interaction between citizens and institutions for self-efficacy and learning:

> I feel that when people are actually involved with something, then they feel that their voice is being heard and it can make them feel good about themselves, if they can make a difference at all, you know…the more you get involved, the more you learn about things as well.

3.1.3 External impediments

Lack of time and lack of awareness of relevant activities are the last obstacles mentioned by the informants. Although these have been usually presented in the literature as personal barriers related to people's lack of interest, the way informants described them illustrates that their source might be external and leading to, rather than being led by, lack of interest. Time scarcity is the most mentioned obstacle to engagement. Several parents motivate it with the active choice to devote their limited free time to their children's interests rather than their own. When having children at home intersects with a time-intensive job, the time to devote to personal interests becomes even less. Paul (47, Woodcutter) is very interested in technology, follows some online courses, and has conversations with his teenage kid about science, but when I ask him if he follows science offline at talks or other events he replies:

> Not so much. Because unfortunately, my work is.. I'm up at 4:00 in the morning and by the time I get home, you know, I'm cooking. Walk the dog, make the kids ready. I'm broken. Monday-Thursday broken. It's exhausting. […] Obviously, if we didn't work, there'd be a different level of engagement with the world. Yeah, I guess that's it.

Paul does not represent an exception concerning the requirements and fatigue produced by his job. Other informants mentioned similar feelings. This suggests that the demands of engagement might not align well with the capabilities and needs of many workers within the existing social structure. As Victoria (32, Masseuse) observes when reflecting about the lack of popular participation in demonstrations: "to protest something, you have to physically go there. And you would have to take the day off work, which means losing a day´s pay. Which means not paying your rent".

Concluding, the empirical evidence presented here contributes to the discourse on sources and implications of science disengagement. The excerpts challenge the assumption that people, especially those who *perceive* themselves as disengaged or come from lower socio-economic backgrounds, do not value or appreciate science and, thus, lack interest in it. I propose that the obstacles presented, along with the perception of science as a "closed club" (Romiya, 42, Clinical Support Desk Nurse), fuel this lack of interest. Thus, to address the issue of science disengagement, science communication efforts that seek to make science more attractive to a wider public seem to be destined to fail if these structural obstacles are not addressed.

Dissatisfaction about governmental actions can translate into frustration and avoidance of contact with institutions, but it can also motivate private actions. Sustainability was often mentioned in this regard when discussing personal forms of engagement although with reservations on their efficacy, as Evelyn (52, ex-Nursery Nurse) mentions:

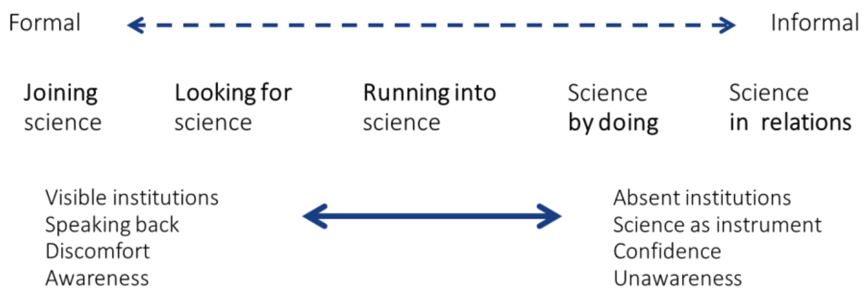
> I would always try to take public transport where I can. And being vegetarian, I eat a lot of vegan food that makes a big impact on the environment. I always recycle. I don't know how much of an impact that makes though [laughs]. I always fill up bottles in between chores and I water my plants with them.

The value of such actions of informal engagement was not discussed during the interviews, but informants were inquired about their formal or informal civic engagement. They were more comfortable discussing this concept and expressing their views, and overall, many seemed to be engaged with society in a positive manner. The next section includes informants' descriptions of their daily encounters with science, which often appear to fall outside established forms of engagement and thus might go unobserved.

3.2 Science engagement “in practice”

Participants reported that encounters with science happen in a variety of ways and have diverse aims. Overall, their encounters with science align with the formal/informal distinction for civic participation (Bherer et al., 2023). Since in this case achieving a distinction between formal and informal ways of meeting science is not a straightforward task, these will be considered as two ends of a continuum. The *formal* end of the continuum is characterized by the existence of an institutional or semi-institutional source of science, which may be a university or a science communication online source or the news. The *informal* end describes manners of meeting science that are lacking an institutional actor and in which individuals mainly re-shape and use science and scientific knowledge privately. Structuring this part of the analysis in these terms provides a valuable analytical lens for examining the nuanced characteristics of these interactions in relation to their proximity or distance from institutional structures. Indeed, informants’ experiences of science vary along this spectrum, offering insights into their perceptions of science as a concept and the role of institutional setup in its dissemination. The elements along this continuum are five and are described below: *joining* science, *looking for* science, *running into* science, *science by doing* and *science in relations*. Figure 1 is a display of these five dimensions along the continuum.

Figure 1. Display of the elements of the formal informal continuum and related characteristics.



3.2.1 Joining science

Joining science can be considered as the instance in which the scientific institutional setting is most present. Indeed, it describes active and co-creative ways of engaging with science that take place through or at official scientific institutions and are initiated by scientists or researchers. The forms of joining science mentioned by the informants are online surveys or experiments administered by or at universities, but also activities of data gathering as citizen scientists or participants in medical trials. Some of the reasons for taking part in these activities are socialization needs, abundance of free time, but also willingness to help, sense of duty, and curiosity. Mildred (40, Nurse Assistant) exemplifies these feelings when asked about her offline contact with science:

> Yeah I see a lot of posts up on Facebook, or research that will come out. So I put myself forward for a lot of the research as well. I'm quite happy to do, like as today, do interviews. I'm quite happy to help. I think it's really interesting. […] And I do often look for things on the internet, to see if people are looking for, you know, volunteers to take part in research. So I do enjoy it and I am always happy to be involved.

these initiatives are undertaken by less than half of the informants and are often related to other activities or interests, or represent a custom passed down in the family. Ruth (69, Retired Civil Servant Commissioner) is involved in medical trials, her daughters have signed up for studies at the University with their own kids, and her own aunt “when she passed away, she left her body to medical science, and that's something as a family, we would be quite happy to do”.

3.2.2 Looking for science

Looking for science is the second step in the continuum from formal to informal science encounters and includes active procurement by individuals of science related information or content. The reasons mentioned are most often a need for information, entertainment, or a mix of these. For information search, the online environment is unsurprisingly the most common, if not the only source used. The outlets mentioned are social media, online lectures, online courses, or more generally the internet. Searching for scientific information online is praised for being readily accessible, up-to-date and for offering a variety of points of view. However these come with drawbacks. Discerning the legitimacy of the sources and managing the overwhelming amount of information are the two most common difficulties faced by the participants. Maeve (56, ex-Hairdresser), who describes herself as not academic and nervous towards science knowledge, reports that:

> Even recently looking into the menopause stuff. Looking in to see what was best and how… and I just ended up getting so confused with the whole thing. I've got better knowledge of it now, but there were times when I could have sat and read some of that stuff, but I chose not to because it was too overwhelming. I couldn't take it in because it was too sciency. And I didn't understand it.

Informants also reach out to science for entertainment purposes. Examples of this are visiting science museums, reading science fiction books or related movies, and watching tv shows. Visiting museums is mostly mentioned in relation with the need to provide entertainment to young kids and rarely mentioned as an appealing activity for adults, as described by Valerie (46, Home Care Aide):

> Do I want to go to the science museum? No, thanks. […] I used to take my kid all the time […] and that I really enjoyed, but I was watching my kid learn. […] For me, it's just boring. Press a button and it talks to you and tells you a little bit about it. And then we're back to reading. […] If it's lots of information and I'm trying to read it, there holds no enjoyment for me. And I don't understand. So I wouldn't go, it just wouldn't be my sort of thing to go to.

Documentaries are by far the most mentioned source of infotainment, besides science books and the work of online science communicators. Television and streaming platforms seem to be the most common providers of documentaries, whose topics range from natural to social and psychological sciences. These expressions of science communications are generally praised for their clarity and accessibility, although at times this simplicity is criticized for being taken too far. Sylvia (46, Homemaker) when commenting a documentary about mushrooms that recently appeared on an online streaming platform mentions that:

> Honestly, it's really interesting and it explains things to you in really simplex views. […] It goes a bit too far with the “oh, my mum's got breast cancer and she got cured with a mushroom”. It's taken a little bit too far. I liked it up to that point, but now you're just being silly. And then they just go into the scientific proof of it […] but I'm still very wary because it is scientific proof but it didn't really go into the *proof* bit of it... Is more of a "you say so proof."

3.2.3 Running into science

Running into science marks a midpoint in the continuum, describing participants' access to science as an accidental and passive way while performing some other activity. Common situations reported by informants to come across science are through the news and scrolling through social media or being online, but also going to the doctor, and listening to the radio. Nathan (35, Web Developer) when asked about looking for information online mentions that he might passively come across scientific information on social media as they "can work as a driver to keep certain things in your way, rather than just saying, like I seek out or I search for science topics on social media".

These encounters with science can be purely casual, as in the case of the news, but at times are generated from a preceding interest by the individuals. Indeed, they might receive notifications or alerts of new content in some online pages whose updates they are interested in receiving or they might select a particular media source knowing they might come across some science content. Abigail (75, Retired), a regular radio listener, expresses this idea in the first lines of the interview while also describing the personal value of science communication programs:

> I'm addicted to Radio 4, and always have been. In fact, that's what's substantially educated me in many ways, or certainly given me much more knowledge of things and understanding of some subjects I wasn't previously interested in. Actually, one of them, funny enough, being science. […] When I have had the opportunity of listening to it, when working, certainly the evenings […] I found that some of the science programs have been actually quite interesting.

This passive and unplanned way of meeting science does not always end with itself. Besides potentially turning into a routine as Abigail explained, the encounter may generate curiosity and the wish to investigate further. That is, the casual *running into* science might lead to the more proactive *looking for* science. Eleanor (38, Homemaker) follows online science communication and humor and mentions a, in her words "not very nice", example of this link:

> It does spark your curiosity, the memes, because if you see a person and you don't understand the meme and you're like: Who's this person? What is this meme? [..] Marie Curie, obviously I know the important work that she's done. But then I saw a meme saying, "oh Mary, you're really glowing today". And I thought, what's so funny about that? I had to google it. And it's because obviously she dealt with radiation, and she didn't know the outcome of radiation. She obviously also died from it, but I never knew that.

3.2.4 Science by doing

The science by doing dimension describes the concrete situations during work or free time in which science or science knowledge is needed, implemented, and recognized by the interviewees. Considering the continuum, this dimension finds its place towards the informal end, as these encounters are often situated further away from institutional outlets. Nevertheless, the continuum still holds as a pertinent framework for the elements explored within this dimension, which often span across levels of formality. It is interesting to notice that the recognition of science often took place during the interview, which at times surprised the informants themselves. Several participants mentioned considering science in alienating or estranged terms by default, and the discussions we had during the interviews made them realize otherwise. As Scarlet (55, Actor) mentioned:

> I am realizing that science is really more part of my life than I thought it was really […] I would have sort of started this by thinking "Oh, I don't know about science. I mean I am not a scientist. I don't have anything to do with science". But yes, as we discuss I realize it is, I've got tendrils in different areas of science. Even if it's only a little bit.

These "tendrils" seem to be widespread in everyday life and materialize in various aspects. In their free time, science is often present in: do-it-yourself projects and hobbies, understanding gems when making jewelry, knowing plants when gardening, or getting exact calculations when taking measurements; kitchen science, when cleaning, cooking, or getting a baking recipe straight; lifestyle choices such as in health and wellbeing related situations, when following a nutrition or sport plan, managing menopause or learning skincare treatments; and finally when trying to build more sustainable everyday habits. Activities such as reducing the household's carbon footprint or recycling are not always immediately recognized as motivated by a scientific reason, as Valerie (46, Home Care Aide) expresses when asked if she ever thought about sustainability and environment issues in relation to science: "Nope. Never even thought that far. Now, look at me. Everything's science. I have just evolved. [Laughs]". Additionally, as for the case of *running into science*, it can happen that these casual, informal, and unstructured occasions to meet science develop into more articulated science interests. Victoria (32, Masseuse) exemplifies well this process:

> Victoria: Google Lens helps me a lot with like plants identification, finding out what plants are and whether you can eat them or not or what they´re use for so that's a great tool.
>
> Interviewer: Are you interested in foraging then?
>
> Victoria: Yeah. I think it's really cool. But that, again, that came from gaming, which is really dumb, like there´s a game on my phone. And like in the game you have to go around and get like flowers and then you use them to cook with. And then I was like, "Uh I wonder if you could do that in real life?" And then of course you can, but I didn't know!

For what concerns informants' working lives, science is not pervasive. Behavioral or social sciences are mentioned by educators or social workers, notions of medical science are mentioned by health care workers, and elements of technology related to computers are mentioned by informants with an office job. In very few cases does job-related science translate into further interest.

3.2.5 Science in relations

Lastly, science seems to have for many of the interviewees a relevant relational dimension. Together with *science by doing*, *science in relations* also finds its place near the informal end of the spectrum while interacting with most of the activities mentioned until now. The aspect that has been mentioned the most by the informants is science being a conversation topic with friends, family, or colleagues. The role of science in these interactions varies through different types of conversations. It can be used as a background source of information, a piece of information found online is validated or corrected by talking with peers, or discussions of political issues can revolve around scientific issues like climate change. Only in a few cases do conversations seem to be about purely scientific topics. Beyond simple conversations, knowledge gathered through previous contact with science is shared as advice and frequently mentioned topics are health and diet or the use of generative artificial intelligence. Conversations among peers, rarely with experts, also have an important role in helping informants digest scientific information that does not feel easy to access otherwise. As Valerie (46, Home Care Aide) explains, gathering information from standard sources has a high entry cost, but it becomes manageable after first approaching it through someone:

> Because I've learned off other people. I learned from people. That's what happens with me. Give me a book: no hope. It's words. It's not evidential to me. Show me. Put me around someone long enough that I learn from them. And then I can go and find my own little way a bit as well.

The importance of face-to-face contact for processing scientific information seems to be a relevant issue among informants. When describing their ideas of how their engagement with science could be improved, the need for more human contact with science was a recurrent theme. Ruth (69, Retired Civil Servant Commissioner) exemplifies well this need of human interaction when describing “a science innovation center, we have the Art center here, it would be nice to have a science equivalent” in order to find someone able to explain everyday science needs in a relatable way.

For some informants finding someone with whom to discuss science related topics is a difficult endeavor. Several participants among those who wish to have conversations about science issues report that they do not have enough people around them that are interested in such debates. Victoria (32, Masseuse) ascribes this to not being an academic person or not having an academic network, which she links to her peers’ level of education:

> I'm not very academic and a lot of my friends aren't academic either, so we wouldn't have chats around the table about of this amazing new discovery, […] the people I have around there that wouldn't really interest them. Whereas if I go to an academic friend's house and their parents will be really excited about science, they might all be talking about it together. […] In not so academic families people just assume that you know what you can, no one really questions why.

Some participants addressed this issue by joining social media groups on their science topics of choice. Beyond gathering information, these are used to exchange opinions and have mini conversations that seem to partially satisfy their need for interaction about their interests.

Finally, this relational dimension is often found in the words of informants who are parents, grandparents, or frequently take care of children in their free time. Indeed, science related activities are often used to reinforce bonding with their kids, while also serving as an occasion for parents to revisit and reinforce their understanding of science. The process of discovery, the fascination of the “explained magic” (Hannah, 60, cleaner and ceramicist) are aspects that captivate children while entertaining adults as well. Homework, home experiments and museums are often mentioned as the places where this bonding takes place and memories are created. Beyond the entertaining aspect of science, these occasions are aimed at the kids learning some science fundamentals. Shared opinion is that science education is generally fundamental for young people’s present and future lives, but also to then find a good and well-paying job. Informants perceive scientific knowledge as a basic requirement “to then progress in life” (Mildred, 40, Nurse Assistant) and describe scientific careers as reliable and well paid. This significance of science is considered not only as an intrinsic feature of scientific knowledge, but it is also produced by the structure of the society in which informants are situated, as noted by Romiya (42, Clinical Support Desk Nurse):

> How many musicians will break through? But how many people who study science will make a good enough life? Do you see what I mean? I think you are going to have to hedge your bets. Obviously, I don't explain this to my

> children. They enjoy music. Yes, you can have music. But if you want it as career, you have to have... [a backup plan] We do not have the privilege of that much money or social capital in this country, especially with the class system.

4. Discussion

Overall, the participants of this study meet science through a variety of science communication activities. A wide portion is represented by engagement activities in which science provides information and outlets to satisfy their curiosity or their daily activities, entertainment, conversations, bonding, and socialization occasions. After encountering it voluntarily or casually, participants make use of science content to inform other life instances in which science acts as an enabler. The situations in which they have the possibility to interact or “speak back” (Gibbons, 1999) to science are only present at the formal end of the spectrum and even in this case interactions are limited. The activities included in *joining science* refer only to the participants providing information, data, or their body to science, often with little further knowledge of the purposes of doing so. When inquired about other occasions to meet science offline, apart from those mentioned (e.g. museums), most participants reported not being aware of the availability of any other activity. The motivations given were formulated as hypotheses and using phrases like "probably", "I guess", or "I am not sure". This signals a possible lack of intention in avoiding science communication events, but also the lack of proactivity in seeking out such occasions, as Nathan (35, Web Developer) explains:

> You'd have to actively go look for these things. I don't think I can see things I'm turning down that are science related. It's not that "ah I want to do that, but I'm busy" or anything like that. It's more a case if you're not aware. So, I would have to sort of take a first step to actually seek out things to do if I was to find them.

Placing these activities on the formal – informal continuum highlights the role of the institutional setup of science in driving the public towards or away from science. A recurring theme in the quotes reported is science knowledge and understanding, or the lack thereof. Indeed, in several interviews, talking about science with a science representative (the author) seemed to invoke in the participants feelings of inferiority, lack of understanding, doubt, and discomfort, which were voiced: “I’m probably not very good on your study. I mean, probably you should have gotten someone a bit more intelligent” said unprompted Jolene (69, Retired). It is interesting here to notice that, in connection with results from section 3.1.1 regarding personal deficits, acknowledgements of own lack of understanding were more present during mention of activities situated towards the formal end of the spectrum, although not exclusively with negative connotations. Reading texts containing science information and having to make sense of it unsupervised is considered particularly challenging and can be a driver for science avoidance, but it also leads to socialization aimed at comprehension or increased information seeking. Understanding is mentioned positively when scientific knowledge is mediated by other means of dissemination, like documentaries or media programs, and is not mentioned at all towards the informal end of the spectrum. When it comes to personal or interpersonal science engagement, that is when the institutions of science are less visible, feelings of inferiority are rarely present, and informants are more in control of their relationship with science. At the same time, when science content is made available through outlets that meet their abilities, informants are capable of better managing their feelings of alienation from science and open to encountering it.

5. Conclusion

By means of qualitative interviews, this study is aimed at understanding public engagement with science from the point of view of members of the public. Participants have been prompted to elaborate on what they recognize as science engagement in their daily lives and their reasons for doing so. This way of studying public engagement with science distinguishes itself from existing research as this usually investigates engagement through pre-defined categories in the case of survey research (e.g. Mejlgaard & Stares, 2013) or by implicitly comparing performed engagement against deliberative standards (e.g. Dawson, 2018). This study is structured to combine these perspectives, as the first part includes participants reflections on established engagement initiatives, while the second is an exploration of their own science engagement practice. Analyzing engagement through the eyes of members of the public and their reported perspectives and experiences revealed significant insights for both research and practice of science communication and public engagement with science.

When reflecting on established forms of science engagement, informants do not perceive themselves as engaged and most of their elaborations concern constraints to engagement. Feelings of inferiority and of lack of self-efficacy contribute substantively, together with practical obstacles, to their perceived disengagement in science-related activities. From participants' words, issues of science knowledge deficit and lack of understanding of processes of science and decision-making certainly emerge. Nevertheless, these become obstacles to engagement when they are linked to personal experiences and practical issues. As noted above, similar feelings are associated with activities located towards the formal end of the continuum, where traditional science institutions are more visible and interaction is low (*joining science*, *looking for science*). The discomfort felt by the participants around these activities is alleviated when science knowledge is freely employed as an instrument (*science by doing*) or mediated by accessible and relatable science communication (*looking for science*, *running into science*), or through interpersonal relationships (*science in relations*). Hence, as "inclusion is not as easy as getting people through the (museum's) door" (Dawson, 2018), so making science available or visible is not enough to create a relationship with the public. Life experiences, personality and everyday situations intersect with the way the institution of science is received and including this acknowledgement in ideations of engagement initiatives seems crucial. Finding the right balance to reach and engage as many members of the public and social groups as possible necessitates careful understanding of the implications that social contexts entail.

Another point worth mentioning regarding the obstacles to engagement is the relationship between external impediments and lack of interest. Previous research focusing on the barriers to engagement has shown that these are the main factors discouraging public engagement with science (e.g. Dryer et al., 2021). For some members of the public this might be the case, and it would certainly not be realistic nor useful to attribute fundamental interest in science activities to each and every member of the population. However, the reflections included in this study challenge the implicit assumption that material barriers are driven by lack of interest and suggest that, in some cases, the opposite might be true. What emerges from the interviews is that the way in which engagement activities are organized often fails to help members of the population fulfil the rights and duties of their role as scientific citizens described in the introduction. Citizens panel meetings organized at 11am on a working day, as mentioned by Ruth (69, ex-public employee), do not take into consideration possibilities, and needs of a large part of the population, leading to their lack of participation while depriving them of the choice to do so. Tackling such issues within existing engagement instruments is certainly challenging. For example, modifying working hours or workloads of working members of the public would provide them with the choice to engage or not in deliberative activities, but requires structural changes that can hardly be achieved by science communication alone. In this context, exploring the ways in which the public encounters science in everyday life highlights potential additional avenues for science engagement.

Exploring informants' own experiences with science and expanding on the multifaceted realizations of science engagement is fruitful to meaningfully understand a wide portion of the public, usually considered *disengaged*. Informants felt more at ease in discussing personal and informal interactions with science, beyond established forms of engagement. Activities of civic involvement, such as recycling and conducting a sustainable lifestyle, are everyday practices in which science is recognized. Notably, most study participants became aware of the involvement of science in these daily actions only during the interview, which elicited positive emotions of surprise and self-discovery. When made aware of their engagement with science through simple daily activities, informants' words reported feelings of contentedness and self-satisfaction, which recall recent discussions on the importance of considering emotion of pleasure and enjoyment as drivers of science engagement (Davies, 2015). Practical applications of science constitute a trend recently explored by science communicators (Huber et al., 2019) for modifying daily habits that has been observed to elicit mixed outcomes in the population (Scharrer et al., 2017). Further research may explore the possible link between feelings of contentedness and self-satisfaction for engaging successfully in simple science activities and positive personal dispositions towards science. Moreover, when elaborating on the importance of science engagement, informants most often mentioned personal gains related to science's ability to enable them to be better human beings, rather than more knowledgeable citizens. This recalls science's potential to enrich not only civic consciousness, which is already present in many informants, by also the quality of their personal lives. As noted by Marres (2016) and Carrel (2023), informal, material, and discrete forms of participation carry the potential to contribute meaningfully to societal engagement and are often carried out by marginalized parts of society (Carrel, 2023). The evidence included in this study is not sufficient to explore this intuition further, but future studies considering the relationship between alternative and established forms of engagement and between forms of engagement and public opinion of science could provide crucial insights.

Finally, reflections on the issues that enable or prevent science engagement might seem to still rely on the assumption that the public is willing to engage with science. This seems indeed to be the case for several informants, which suggests a limitation of this study. Many of the members of the public that decided to join the study present themselves as somewhat interested in science and would like more occasions to engage with it. This indicates that this study's advertisement and recruitment did not reach the part of the population that is fully uninterested in science, which remains underexplored. Nevertheless, participants' insights are still informative in terms of the kind of engagement that they would welcome, especially in relation to deliberation. Informants perceive that public preferences and needs are undervalued in decision-making on science issues and in science and technology development, however this is not followed by the will to get involved. Several factors might be related to the latter point, including elements discussed in previous paragraphs. At the same time, informants highlight the need for transparency, public responsibility and accountability of institutions that has been already observed to be lacking in public engagement research (Árnason, 2013). Future research might address this link between public needs and institutional response employing insights from research on integrity and responsible innovation as a means to addressing public concerns (e.g. Schomberg, 2013).

By exploring engagement beyond the prevailing notion of deliberative initiatives, this study provides empirical evidence that such a defined notion of engagement marginalizes a wide category of individuals and actions. Reversing the perspective from which science engagement is narrated serves to start a discussion on the boundaries of relevant public engagement with science which might be informative for both engagement research, in terms of building a more equitable research framework, and practice, as it can lead to new avenues for science communication. Although classifying mushroom picking during free time as relevant science engagement might be a matter of debate, the broader perspective advocated here encourages an exploration of the engagement potential of the various ways in which individuals connect with science in their daily lives and fosters a more comprehensive understanding of science's role in both civic and personal spheres.

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Beyond deliberation.
Exploring perceptions and experiences of science (dis)engagement in England.

Supplemental material

Content

1. Descriptives Table
2. Interview Guide
3. Coding Scheme

1. Descriptives Table

Pseudonym	Age	Employment	Education	Born in	Kids	Grandkids
Emmanuel	27	IT Staff - Web programming	Tertiary Education (Information Technologies)	Ghana	No	No
Grace	30	Unemployed	Secondary Education	UK	No	No
Victoria	32	Masseuse	Secondary Education	UK	No	No
Shannon	33	Mental Health Nurse	Tertiary Education (Psychology)	UK	No	No
Nathan	35	Web Developer	Tertiary Education (Graphic Design)	UK	Yes	No
Eleanor	38	Homemaker - Stay at home mum	Not finished Secondary Education	South Africa	Yes	No
Harriet	38	Primary School Teacher	Tertiary Education (Psychology)	UK	Yes	No
Amelia	39	Homemaker - Stay at home mum	Secondary Education	UK	Yes	No
Mildred	40	Nurse Assistant	Tertiary Education (Foundational Degree)	UK	Yes	No
Romiya	42	Clinical Support Desk Nurse	Tertiary Education (Nursing)	Kenya	Yes	No
Olivia	45	Teacher: English and Mathematics	Tertiary Education (Sociology)	UK	No	No
Sylvia	46	Homemaker	Not finished Secondary Education	UK	Yes	No
Paul	47	Woodcutter	Secondary Education	UK	Yes	No
William	47	Teacher: Civic Education - Ex Military	Secondary Education	UK	Yes	No
Valerie	47	Home Care Aide	Secondary Education	UK	Yes	No
Nicholas	52	Unemployed - Glass Seller	Not finished Secondary Education	UK / Trinidad & Tobago	Yes	No
Evelyn	52	ex-Nursery Nurse - Unemployed	Vocational Training	UK	Yes	Yes
Scarlet	55	Actress	Vocational Training (Drama School)	UK	Yes	No
Maeve	56	ex-Hairdresser - Unemployed	Not finished Secondary Education	UK	Yes	Yes
Hannah	60	Cleaner - Ceramicist Artist	Tertiary Education (Art Academy)	UK	No	No
Suzanne	61	Administrative Support - Funeral Celebration	Secondary Education	UK	Yes	No
Logan	63	Landlord - ex-Driving Instructor	Not finished Secondary Education	UK	Yes	Not Mentioned
Ruth	69	Retired - ex-Civil Servant Commissioner	Tertiary Education (Housing Studies)	UK	Yes	Yes
Jolene	69	Retired	Not finished Secondary Education	UK	Yes	Yes
Abigail	75	Retired - Librarian	Tertiary Education (Sociology)	UK	Yes	Yes

2. Interview Guide

Thank you for agreeing to participate!

Just as a recap, through this and other interviews I would like to understand how science is perceived and experienced by members of the public. This will help me telling a story about how people relate to science from their point of view. I am not interested in promoting or devaluing science, I am not trying to prove a point there are right or wrong answers, I am just trying to understand what you think.

Since I would like to know about your personal experiences, you decide how much you want to tell me, you can skip questions or even stop the interview or if you don't understand something just tell me and we'll work it out.

I would like to record this conversation with a voice recorder, so I can report exactly what you tell me without relying on my memory. This recording will not be made public, I will transcribe it and then delete it when I am done. I will also not use your real name when reporting the results of the study. Is everything ok for you? Do you have any questions?

Background / Warm-up

1. First, I was hoping you could tell me something about yourself? Maybe you can start from what you do for a living if you have an employment or how you spend your days?

Probes: Have you had a previous employment? How did you end up working with this? What do you like about it?

Personal Relationship with Science

2. Can you tell me the first three words that come to your mind if I ask you to think about "science"?

3. What science disciplines come to your mind if I ask you to think about "science"?

4. What would you say are your feelings toward science? Are you interested, doubtful, curious, intimidated, disappointed, apathic?

• Can you recall if you had similar feelings when you were in school? Can you think anything in the environment you grew up in – as in your parent, your friends or your living area – had an effect on how you regard science?

• Can you recall an experience related to science?

• Do you think that something about your job ever influenced your opinion of science?

Encountering science in daily life

5. In your daily life, can you think of any moment in which you are in contact with science in any way or in which some science content is involved?

Probes: for example, if you had to think about your job? If you had to think about your free time?

• [*if no*] Why do you think that is the case?

If not mentioned, ask about social media:

• What about social media, do you happen to come across any science content there?

How do you interact with the content?

6. Do you find it difficult to access science content or activities?

• Do you ever come across science content you find disturbing?

• Do you think that the area you live in, or your daily tasks make it more difficult for you to access science? How?

7. Can you recall any situation in which some bits of science knowledge changed your opinion on something?

Attributing value to science engagement

9. Until now we talked about the ways in which you come across science, now I would like to reflect on the value of science for you or in society. Independently from whether you do or do not actively engage in any practice related to science in your daily life, how would you rank these three items I give you from least to most importance for you?

a) Be up to date with science developments.
b) Make your voice heard in government decision-making on science related issues.
c) Having the possibility to participate in shaping science content.

• Can you tell me why you think so?

10. Do you think that someone should engage in these activities? [*If yes*] Who would they be?

• Can you explain me why you think so?

Linking science and civic engagement

7. Moving to other areas of social life as civic or political participation. When it comes to formal participation, such as voting, going to council assembly or a themed public meeting, joining a protest, doing charity work, how active or involved would you say you are – to the extent that you are allowed to (*if foreigner*)?

• [*If relevant*] Can you think of a recent example?

• Can you tell me about why you do […] / don't?

8. What about informal civic or political participation instead, such as changing -or not- lifestyle or food habits for political reasons or boycotting products or brands, would you recognize yourself in any of this?

• [*If relevant*] Can you think of a recent example?

• Can you tell me about why you do […] / don't?

Ending

11. After these reflections, do you wish you had more or different ways of encountering science or scientists? Is there something that science institutions or the local council or any institution you can think of can do to make science feel closer to you in any way?

• Could you make an example?

Demographics (if not already provided)

Age, education, (past)employment, (past)area of living, children, nationality, parents' nationality.

3. Coding Scheme

Theme / Code Name	Count	Content Description
Science Engagement in Theory Codes relative to participants' perspectives on science engagement, especially on elements from question 9.		
Reasons to engage with science	Codes referring to participant's motivations to engage with science	
Influence science	1	Describing the possibility to influence science development
Personal inspiration	3	Describing the role of science and scientists as personal inspiration
Scientific knowledge for better life	9	Describing the gain in science knowledge from engagement, useful to live a "better" life
Science funding	2	Describing science's need for public engagement and support to secure funding
Reasons not to engage with science	Codes referring to participants' motivation not to engage with science	
Personal Deficits	Codes referring to mentions of personal faults as reasons for disengagement	
Intelligence for science	8	Describing the need a link between being clever and being in contact with science
Lack of skills / understanding	10	Describing respondents' own inability to understand science
Science as scary	4	Describing science as scary and difficult to approach
Lack of Relevance	Codes referring to mentions of lack of relevance for them	
Self-efficacy	10	Describing feeling of not being heard by institutions
Not relevant	7	Describing lack of relevance of being in contact with science
External Impediments	Codes referring to mentions of practical obstacles to science engagement	
Lack of opportunities - awareness	2	Describing lack of awareness or availability of offline engagement opportunities
Lack of time	10	Describing respondents' own lack of time for engagement
Outcome – leave to the experts	8	Describing willingness to leave science to experts as an outcome of previously mentioned impediments
Science as a closed club	5	Describing respondents' description of science as inaccessible

Theme / Code Name	Count	Content Description
Deliberative Audience	9	Describing the characteristics of people who should take part in deliberative activities
Science Engagement in Practice Codes relative to participants’ experiences of science engagement in everyday life		
Joining science	Codes referring to formalized science engagement activities	
Citizen science	2	Describing activities of citizen science as such or similar
Experiments / Surveys	8	Describing being involved in experiments or surveys organized by the university online or at a university lab
Medical trials	3	Describing taking part in medical trials
Looking for science	Codes referring to mentions of active and voluntary search for science	
Entertainment	Codes referring to activities aimed at entertainment	
Science Fiction	4	Describing mentions of SciFi material (books, movies..)
Science / Art museum	3	Describing mentions of museums of any kind for themselves
Museum with Kids	8	Describing mentions of museums of any kind for kids
Science talk	2	Describing mentions of attending any science talk offline
TV Show	6	Describing mentions of TV Shows when mentioning science encounters (mostly about kids shows or social science)
Information	Codes referring to activities aimed at getting information	
Offline Lectures	2	Describing mentions of attending any science lecture offline
Online - Too much info	8	Describing feelings of overwhelm given by online information
Online - Unspecified	21	Describing mentions of unspecified retrieval of information online
Online - Courses	3	Describing attendance of online courses on any science
Online - Legitimacy	7	Describing problematization of legitimacy of online information
Online - Social Media	6	Describing looking for information on social media
Research Articles	1	Describing mentions of retrieval of science articles
Science Magazines	1	Describing mentions of use of science related magazines

Theme / Code Name	Count	Content Description
Unspecified Reading	2	Describing unspecified reading about science
Infotainment	Codes referring to activities aimed at learning while being entertained	
Online - SciComm	1	Describing mentions of science communication content online
Radio	1	Describing use of radio programs with science content
Books	4	Describing reading of science related educational or novels
TV Show	9	Describing tv shows as documentaries of lectures
Running into science	Codes referring to passive or involuntary science encounters	
Doctor	7	Describing meeting science at the doctors / for medical reasons
News	15	Describing meeting science in the news
News - Legitimacy	1	Describing problematization of legitimacy of news
Have to look for it	10	Describing not encountering science without will
Online - Social Media	14	Describing encountering science online in social media
Radio	2	Describing encountering science through the radio
Online - SciComm	5	Describing encountering science online through science communication activities
Science by doing	Codes referring to using science while undertaking other activities	
Free Time	Codes referring to free time activities	
Sustainability	9	Describing activities related to sustainability / recycling
Not thought as science before	6	Describing the contextual realization that sustainability has to do with science
DIY	8	Describing Do-it-yourself activities involving science
Health	9	Describing activities related to health (fitness, food..)
Hobby	3	Describing science-related general hobbies
Kitchen	6	Describing science-related kitchen activities
Job	Codes referring to job related activities	

Theme / Code Name	Count	Content Description
Human subjects	10	Describing job-related use of science involving human subjects
Objects	6	Describing job related use of science involving objects
Not actively aware before the interview	6	Describing the contextual realization that job activities have to do with science
Science in relations	Codes referring to the involvement of science in interpersonal relations	
Advice Sharing	3	Describing sharing of advice based on previously acquired science information
Conversation Topic	20	Describing the employment of science info in conversations
Not easy to find people	5	Describing the difficulties of finding people with whom to have science-related conversations
Science to kids - Bonding	11	Describing instances in which science helps adult-kid bonding
Science to kids - Edutainment	7	Describing instances in which science in promoted to kids for entertainment and education
Science to kids - Future	6	Describing instances in which adults mention that promoting science to kids is important for their future employment
Social media groups	6	Describing using social media groups to discuss science content
Make up for difficulty of reading	2	Describing instances in which conversations help with making sense of science
No, alone activity	2	Describing mentions of science as a private activity
Offline Engagement	Codes referring to mentions	
Leave science to people who know	3	Describing unwillingness to engage in offline events and rather leaving them to more experienced people
Not useful	2	Describing perceptions of lack of utility of offline events
Not aware	16	Describing mentions of lack of awareness of offline events
Access to science	Codes mainly referring to answers to last question about wishes for further science access	
Enough, no more	4	Describing satisfaction with current situation
Not enough, want more	14	Describing wishes for further science engagement

Chapter 7
Discussion and Conclusion

In this dissertation, I aimed at investigating public (dis)engagement with science through the lens of the public to provide insights to the question *how do socio-demographic characteristics interact with public engagement with science?* By exploring this question, I aimed at observing the role that social, cultural, and economic factors have for individuals' relationship with science and their science (dis)engagement. Moreover, this study adopts a special focus on the disengaged public, often characterized by a disadvantaged socio-demographic profile. Rather than framing this part of the public as deficient and alienated towards science, in this study I applied an exploratory perspective to build a bottom-up picture of their (dis)engagement, drawing evidence from the public themselves, interacting with scientific institutions, within their social context. I argue that the relevance of this approach to further understanding (dis)engagement habits lies in the opportunities that the results offer to science communication practice and policy making.

In chapter 2, I highlighted how this study on public engagement with science builds on concepts belonging to three domains: characteristics of modern societies, the structure of science and the role of individual citizens. The concepts of Knowledge and Digital Society helped me in describing the social setting in which the relationship investigated takes place. The stark encompassing relevance of science in contemporary societies and the pervasiveness of digital media are enlightening framings when discussing interactions between science and the public. The concepts of Mode 2 of knowledge production and Lay Expertise define the very idea of public engagement with science and the structure of science in which it emerged. Moreover, throughout this dissertation I aimed at applying a *lay expertise* approach while interrogating people's (dis)engagement habits to obtain a grassroot image of (dis)engagement. Finally, the theoretical concepts of Scientific Citizenship and Social Inequality allowed me to frame the role of individuals in the new social context of science with personal rights and duties, but also social constraints. These two concepts used in tandem allowed me to highlight the tension between individual and institutional responsibilities in creating an equal and engaged society. This conceptual background, together with an overview of the definitions, goals, and motivations for (dis)engagement emerging from the academic literature, led me to outline three research sub-questions that guided the empirical studies. As a first step, I set out to investigate *how can citizens be defined according to their engagement with science?* Secondly, I turn to observing individuals' science attitudes in this relationship by asking *what is the role of science attitudes in the relationship between socio-demographic characteristics and engagement with science?* Finally, to complete this bottom-up analysis of engagement, I reverse the first question as *how can engagement with science be defined from the public's own perspective?* In the next section, I describe how each of the three empirical chapters addresses a corresponding sub-question.

In chapter 3, I discussed the methodological approach overarching the project and the specific design choices I applied in each empirical study. To address the main research question, I employed both secondary quantitative survey data and qualitative interviews conducted as part of this dissertation. Initially, I described quantitatively Europeans through established indicators of public engagement with science used in the Eurobarometer survey (2021). Then, employing the same data, I investigated the role of science attitudes for the engagement choices of different social groups. Finally, by interviewing 25 members of the public with socio demographic characteristics generally associated with low levels of engagement, I studied lay perceptions and experiences of science. This process produced empirical results that mutually reinforce and challenge each other while highlighting gains and limitations of different ways of understanding engagement.

Chapters 4 to 6 include the empirical studies in the form of three scientific articles. These studies contribute to a comprehensive understanding of public engagement with science by examining it through different lenses. In remining of this final chapter, I summarize the central findings of the empirical studies included in this dissertation and discuss their main contributions in addressing the research questions while highlighting the ways in which they complement each other. I then proceed to lay out the overall contributions of the dissertation and the reflections it generates. Finally, I discuss the limitations of this study and possible future research avenues. I end the chapter by drawing an overall conclusion and policy implications.

7.1 Summary of the empirical results

In article A, according to the frequency with which Europeans perform various established activities of public engagement with science, I was able to quantitatively discern two types (or dimensions) of engagement. One is characterized by culture enhancing activities such as going to museums, watching documentaries, and talking to friends and family about science and technology related issues, which I labelled as *informative engagement*. The other describes a broader form of engagement, including informative activities mentioned earlier, but also deliberative activities such as signing petitions, joining demonstrations, or attending public meetings, and co-creative activities such as providing personal data for scientific research and taking part in clinical trials. I have labelled this as *general engagement*. Based on these two forms of engagement, I was able to answer the first research sub-question and describe Europeans according to four groups: *disengaged*, *aware*, *invested*, and *proactive*. Not surprisingly, the *disengaged*, who are the largest group (around half of the Europeans sampled), have low levels of both forms of engagement described above. The other three groups represent different configurations of engagement, with consistently high levels of informative engagement and varying degrees of general engagement. Lowest among the *aware*, medium among the *invested* and highest among the *proactive*. In agreement with existing evidence, in the final part of this study I observe a possible relationship between social status and (dis)engagement: the members of the public included in the disengaged group seem to have disadvantaged socio-demographic characteristics. This insight is key to interpret these results and the two studies that follow this first one. Through the combination of the two types of engagement, this analysis contributes to describing different forms of active engagement, but disengagement remains essentially characterized by the absence of engagement. Coupled with evidence of a marked socio-demographic gap between the disengaged group and the other three, this first study contributed to motivating the subsequent direction of the dissertation. Indeed, further analyses focus on investigating the possible relationship between disengagement and social status in two ways: first, I investigate this relationship quantitatively while interrogating the role of science attitudes and deference towards authorities; last, I explore qualitatively perceptions and experiences of science among members of the public to understand engagement beyond conventional definitions.

In article B, I investigated further the socio-demographic gap in (dis)engagement with science by testing the expectation that attitudes towards science might mediate this relationship. First, I observed that, indeed, the higher the individuals' social status, the more engaged they are in both forms of engagement, informative and general. Examining, then, the role of attitudes towards science in this relationship, I gather a mixed answer to the second research sub-question. I find that overall attitudes towards science are weakly related to the socio-economic gap in public engagement with science, with interest for science and technology developments being the only common thread between socio-economic status and (informative) engagement. Europeans with more advantaged social status seem more interested in science and, in turn, more engaged, especially in an informative way. This result is not novel in literature of public understanding of science, but it is often interpreted in deterministic ways, associating the lower engagement of the disadvantaged with their lower education or science literacy, leaving structural influences under-developed. In the final study, I attempt to expand on this with qualitative insights. Moreover, among the attitudes towards science considered, I focused particularly on the role of technocratic tolerance. This is the extent to which the public is willing to defer to experts for decisions on science and technology. This analysis indicates that reliance on expert authority for decision-making on science-related issues is less prevalent among individuals of lower socio-economic status. This is puzzling when associated with the evidence that lower social status is also related to less personal engagement with science. Studies employing previous versions of the Eurobarometer have shown similar results and provided, but not tested, various alternative explanations (Mejlgaard & Stares, 2013; Makarovs & Achterberg, 2018). To inform further interpretations, in the last study, I delved deeper into lay people's relationship with science to enrich our understanding of this phenomenon.

Through the interviews collected for article C, I was able to observe further nuances of public (dis)engagement with science. After initially reporting an overall lack of engagement with science, participants mention being engaged in a variety of informal and personal science-related practices. Understanding these practices along an original continuum of formal – informal activities allowed me to answer the last research sub-question while exploring the role of the institutional setup of science and the implications this has for lay engagement. When discussing established forms of engagement, characterized by a clear presence and role of formal science institutions, participants do not perceive themselves as engaged. However, when prompted to describe any instances and daily activities in which they feel proximate to science, a diverse array of responses emerges. In contrast with results from article A, reporting that non-engagement is the most common form of engagement, this exploration of practices among the informants reveals that *awareness* has a key role for detection and reporting of engagement. When formalized realizations of science and science institutions are missing, informants often do not recognize their engagement with science even if in fact they practice it. At the same time, when it comes to the obstacles for further engagement, the analysis highlights the interaction between personal and systemic factors in hindering engagement. Personal responsibilities, such as lack of time, awareness, understanding and self-efficacy, seem to go in tandem with the rights and duties (e.g. work, family time) that come with being citizens embedded in society. Behind the "lack of interest" gap that I observed in article B, there may be a variety of meanings and implications for individuals that influence how they navigate between their own possibilities and the opportunities or requirements of engagement.

7.2 Contributions

The methodological and theoretical contributions of this dissertation combined with the empirical evidence gathered aim at being conducive to further reflections on the borders, configurations, and goals of just and equal public engagement with science. In the next paragraphs I outline the principal contributions, while reflections and implications are discussed in the next sections.

Methodologically, this dissertation contributes to the literature on science communication and public understanding of science with an example of fruitful interaction between quantitative and qualitative methods. The existing literature on public engagement with science is informed by quantitative, qualitative, and theoretical studies (e.g. Schäfer et al., 2018; Dawson, 2018; Smallman, 2020), but these insights rarely refer to each other. This is likely due to specialized expertise and practical constraints, but maintaining separations among types of evidence runs the risk of missing valuable interpretations of reality. Although this dissertation is not a textbook example of mixed-methods study, by employing different types of data I attempted at providing a varied and informative interpretation of public engagement with science. The qualitative evidence of various forms of informal *lived engagement* can inform the quantitative results in a continuous exchange able to investigate their potential to improve practice and bridge disciplinary gaps.

Following this, another contribution of this dissertation lies in investigating the possible attitudes-engagement relationship and the link to socio-demographic characteristics and systemic disparities. Research on the determinants of (dis)engagement has contributed to understanding various correlates of (dis)engagement, such as the gains from engagement activities (e.g. Rose et al., 2017) and the reasoning behind engagement (e.g. Jensen et al., 2021). Moreover, there is evidence of a relationship between attitudes towards scientists, deference, and preferences towards public participation in decision making (Brossard & Nisbet, 2007; Howell et al., 2020). Relating to this evidence, in this dissertation I elaborated on the link between individual attitudes and engagement with science, while considering individuals' embeddedness in social contexts. In this way, I was able to approach a recurring explanation of disengagement, lack of interest, while showing possible alternative interpretations.

Another contribution of this dissertation is represented by the application of the *lay expertise* perspective to study engagement on people's own terms. From Wynne's (1996) case study of Cumbrian sheep farmers, the lay perspective has been increasingly incorporated into science and technology development and has produced several valuable contributions in the last decades. The application of this mode of understanding the relationship between science and the public has shaped and directed research on public engagement as well, generating novel insights and challenging perspectives (e.g. Davies, 2017, Marres, 2016). In this dissertation, I contribute to this tradition by not focusing on lay people to better engage them in pre-defined activities, but to include their perspectives as experts of engagement practices. This has allowed me to gather novel insights into people's relationship with science that can contribute to further applications of science communication.

A final contribution of this dissertation is the attention devoted to those excluded from engagement and from science. This is a recent emphasis in research on the science-public relationship. As shown in chapter 2, there has been a growing focus in the recent years on understanding the socio-demographic characteristics of the (dis)engaged public, as well as addressing issues related to power dynamics and lack of justice in engagement and the need for accountability in academic production. This emphasis is exemplified well by the recent special issue of the Journal of Science Communication on "Responsible science communication across the globe" (Achiam et al., 2022). In the introduction to the special issue, the authors refer to the Responsible Research and Innovation framework to highlight the imperative for developing *inclusive, reflexive,* and *co-creative* approaches in science communication research and practice. In this dissertation, I follow this call and avoid resorting to marginalized members of the public only to highlight their disadvantage and exclusion. The three empirical articles contribute in different ways to propose an empowered image of the public by interrogating existing measures of (dis)engagement, its current scope and possible alternatives. The unequal participation in science and relative decision making must be addressed in the next future, but I argue that approaching the excluded as experts of their own engagement has made it possible to uncover nuances of engagement otherwise lost.

7.3 Implications

Taken together, the contributions and the empirical evidence provided through this dissertation prompt several reflections on the borders, configurations, and goals of just and equal public engagement with science. In the next paragraphs I describe these implications for research and practice of public engagement with science by discussing two main points: the borders of (dis)engagement and the role of institutions in this process.

7.3.1 On the borders of (dis)engagement

The results of this study prompt a critical reflection on the conventional approach to the definition of (dis)engagement and its connection with socio-demographic characteristics of the population. The following discussion is articulated in two main points. First, I argue that the current mainstream indicators of public engagement with science might struggle to capture the breadth of the engagement activities, leading to a lack of nuance in describing disengagement. Second, I highlight the importance of reflecting on the breath of (dis)engagement in terms of social justice and increased representation.

Unnuanced disengagement

In the first empirical article, I observe that around half of the Europeans included in the Eurobarometer survey can be categorized as *disengaged* with science, as they almost never partake in any of the activities included in the study (see Table 3 in Chapter 3). The other half of the sample can be considered as *engaged* to different degrees and categorized into three different clusters according to the extent of their engagement. Arguing whether the percentage of (dis)engagement is high or low is beyond the scope of this reflection, rather this discussion focuses on the lack of nuance in the characterization of disengagement. Indeed, the engaged half of the population is not a homogeneous group, which is testified by the differing socio-demographic characteristics across the clusters. Conversely, the disengaged half is confined to a single category, and it has a marked disadvantaged socio-demographic profile. This lack of variation within the definition of disengagement necessarily translates into a limited comprehension of its nature and of the circumstances in which it may result in problematic outcomes. An encompassing and unnuanced definition of the disengaged public is not very informative regarding their level of distance from science and may lead to incautious assessment of their perceptions of science. This is particularly the case in light of the results of article B and C. Europeans with a disadvantaged socio-economic profile are less prone to defer to technical expertise but are less interested in science and engage less with it. At the same time, interviews suggest a more complex interpretation of this evidence, highlighting the interplay of individual and structural responsibilities. Previous research has proposed a definition of problematic disengagement by considering the mismatch between levels of preferred and performed engagement (Mejlgaard & Stares, 2013). The authors argue that when the level of performed engagement is lower than preferred levels, this mismatch is a democratic problem. This represents an interesting and fruitful analytic perspective, although it relies on a restricted operationalization of performed engagement. Included in the analysis, based on a previous version of the Eurobarometer survey, are only indicators of informative and deliberative engagement. It is not possible to determine whether the results of their study would have been different if considering a wider sample of activities, but evidence from this dissertation hints towards the value of introducing further nuances in the categorization of (dis)engagement.

Diversity in representation

Finally, the value of considering the nuances of engagement takes seriously the markedly disadvantaged socio-demographic characteristics of the population characterized as *disengaged*. The *disengaged* cluster in article A shows a disadvantaged socio-demographic profile, evidence confirmed in Article B. At the same time, most of the informants of the qualitative study reporting various forms of informal engagement, have socio-demographic characteristics traditionally associated with little engagement with science. I cannot establish the degree to which these findings generalize, but I argue that they suggest value in a more nuanced approach to (dis)engagement also in terms of diversity and representation. Beyond providing a better understanding of the disengaged population, it would also improve diversity in the representation of engagement practices. Indeed, these results offer an alternative perspective on framing the socio-demographically, economically, or culturally disadvantaged members of the population as less engaged with science (Dawson, 2018). Developing socially representative indicators for engagement with science deviates from uniquely viewing the disadvantaged as deficient, and instead striving to understand the potential of the engagement activities they undertake. In addition, this might provide the opportunity to gain a more detailed understanding of the reasons underlying their (dis)engagement. Though I have no evidence on the effect of alternative engagement measures, I contend that equally focusing on established and alternative engagement forms would provide an understanding of the disadvantaged not as lacking but would highlight the hidden engagements identified in the dissertation. This does not dismiss the importance of public deliberation and the problem that unequal access to deliberative engagement represents. Issues of lack of representation in public engagement in decision-making are relevant and have concrete consequences in exacerbating inequality. However, applying an more inclusive approach to the ways in which disadvantaged social groups actively experience and perceive engagement, including deliberative engagement, might reveal insights able to open avenues for alleviating lack of representation.

These reflections are a proposition for a change of perspective in the way disengagement is conceived and observed, rather than immediate solutions for the socio-demographic gap in engagement. The goal of this dissertation is not to produce practical solutions, but to prompt a reconsideration of conventional notions of engagement with science. By highlighting nuances and urging a shift of perspective, I seek to stimulate the discussion on the conceptualization of (dis)engagement (Burns & Medvecky, 2018) towards opening avenues for reimaging solutions while promoting a more inclusive understanding.

7.3.2 Public deliberation and institutional responsibility

This dissertation does not venture systematically into analyzing the role of institutions for a just public engagement with science, however the evidence collected prompts a reflection on this implication. In chapter 2, I have introduced the concept of *scientific citizenship* and the relative tension in the academic literature between the emphasis given to individual rights and duties and the role of institutions in providing opportunities for these to take place. Recent developments in the literature of science communication point in the same direction, as the special issue introduced above (Achiam et al., 2022) encouraging a sharper focus to "*critically question the societal and institutional structures that govern science communication practices in Europe*" (p.3). Likewise, I observed that in the engagement paradigm carried out until now there has been a mismatch between the emphasis placed on the uptake of deliberative forms of engagement by the population and the responsibility assigned to democratic and scientific institutions. Motivated by the discrepancy observed in article B, between preferences for public participation in decision making and the low personal engagement of disadvantaged groups, I propose this misalignment to be a key factor for future configurations of the relationship between science and the public.

Often the level of public involvement is assessed against the normative ideals of deliberative democracy, which in turn tend to shape the academic discussion on engagement and scientific citizenship (Habermas, 1975; Cohen, 2009, Davies, 2015; Davies & Horst, 2016). Despite the more or less formalized characteristics of deliberative interactions (e.g. town meetings as in Mansbridge, 1980, coffee houses as in Habermas, 1991, street corners and parks as in Sunstein, 2007, or online as for Jensen, 2011, or Sørensen, 2016), they all refer to the ideal that every member of the society should contribute to the achievement of desired policy results. Thus, the level of public engagement is often deemed unsatisfactory because it fails to meet ideals of widespread science literacy and active engagement characteristic of the *model* (*scientific*) *citizen* (Hu, 2024). In this dissertation, I argued for the importance of including people's actual practices and preferences in the discussion of democratic participation. This perspective is not new in the academic literature of public engagement with science. Indeed, Mejlgaard and Stares (2013) have already argued for the importance of taking the public's perspective as a foundation for the elaboration of policies aimed at enhancing engagement, rather than "imposing a particular top-down normative model" (p.671). I build on this framing to propose an expansion of the avenues for engagement while discussing the role of institutions.

Promoting a larger involvement of the public in decision-making on science and technology requires not only increasing opportunities for engagement, but also ensuring a broader representation of public perspectives in science governance. Article B and C provide empirical evidence useful to elaborate on this argumentation. I observed that members of the public from disadvantaged socio-demographic backgrounds favor the consideration of the citizens' perspective in science decision making, but at the same time have lower levels of engagement with science and interest (article B). In addition, the qualitative interviews indicate that among the interviewees discontent was often related to a perceived lack of consideration of public needs in science and technology development and policy. The will to participate actively and directly in the governance of science was almost never mentioned, rather informants stressed the importance of their unmet needs and unheard perspectives, while acknowledging their lack of science knowledge (article C). Thus, to contribute to the (at least) ten-years-old debate on the engagement paradigm relying on scarce knowledge of public preferences for engagement (Sturgis, 2014), this dissertation aims to expand the focus. Discussing the extent to which uninformed public preferences should influence the elaboration of democratic processes is beyond the interests and the reach of the present dissertation. These results suggest a reflection on the responsibility of institutions to be accountable to the public while representing their interests and needs. Besides a *democratic deficit* (Bucchi, 2008; Norris, 2011), prompted by the unmatched desires to engage with science, we can conceptualize a *representation deficit*, produced by the lack of responsiveness and transparency of scientific development and democratic institutions. This observation recalls Árnason's (2013) discussion of the risks that an emphasis on direct participation in deliberation might overlook public accountability and trustworthiness of democratic institutions and the institutional responsibility in maintaining these. This does not suggest disregarding the importance of engagement with science for the public, but instead I argue for expanding the avenues of research on engagement and the ways in which science relates to the general population.

7.4 Limitations

Results from the empirical studies are in dialogue with each other and contribute to producing an informative description of the European public's relationship with science. Nevertheless, they have some relevant limitations, beyond those included in chapter 3, which I address in the following section.

The qualitative insights included in this dissertation are limited by the characteristics of the participants interviewed and the chosen location. Practical constraints coupled with well-documented difficulties in recruiting participants for qualitative interviews, led to the current selection of participants. Given the characteristics of the interviewees, I cannot compare engagement across background, gender, or ethnicity, which limits the results. Furthermore, I cannot argue to have exhausted all potential of engagement activities, as among the informants almost none expressed a complete lack of interest in science. Reaching the uninterested and unwilling population is challenging, although it can reveal important insights into the way science is experienced. Furthermore, locating the analysis in England is interesting for the characteristics of the English social structure and makes it possible to locate the study in a well-researched and, thus, well known context. However, at the same time it must be underlined that the English (and British) context might have been reflected in some of the answers provided by the respondents. Specifically for the instances in which informants perceive that public preferences and needs are undervalued in decision-making and highlight the need for transparency, public responsibility, and accountability of institutions. From the words of the informants, they seemed to be drawing from the at-the-time-recent British political events, which included a rapid turnover of prime ministers and controversies in the administration of the COVID-19 pandemic. I cannot argue that in a different political climate their answers would have been different, though highlighting the possible overlap is in itself interesting.

Informal participation activities have been argued to carry the potential for wider political engagement (Bherer et al., 2023), but the meaning of these activities has been understudied in research of engagement with science. I addressed this call by reporting on informants' contextual reflections on established forms of engagement and describing the variety of ways in which they encounter science in their daily lives. However, while offering valuable insights, it remains a challenge to draw conclusions about the translation of alternative engagement practices into mainstream activities. This dissertation provides initial evidence on the relationship between informal engagement and attitudes towards science, as an exploratory first step. This is partly related to the members of the population that took part in the qualitative interviews, as their opinions of science seem to be rather homogeneous and positive. Although variations exist in the depth of their interest, their overall positive orientation hinders the emergence of evidence on the interplay between informal engagement and science attitudes. This homogeneity could be an indication of "acquiescence bias". However, to mitigate this possibility, I started every interview by clarifying my neutral intentions, I made an effort to create a relaxed and friendly environment, I avoided "yes or no" question formulations, and I often prompted answers by soliciting both complying and not complying options (e.g. examples of engagement, interest in science). Nevertheless, the possibility of acquiescence cannot be ignored. The power imbalance between members of the public (the interviewees) and a member of the institution of science (me) could play a part in this. Nevertheless, I observed that as informants realized the extent of the presence of science in their daily lives, which often took place during the interviews, they showed feelings of self-satisfaction, joy, and self-worth, related to their discovered ability to accomplish anything scientific. From memory and from field notes, I fully believe these realizations to be genuine. While the dissertation does not delve deeply into this phenomenon, recognizing the empowering potential of these science practices could offer valuable insights into the relationship between science and traditionally (described as) disengaged segments of the public.

Finally, time restrictions of this project meant that it was not possible to build on the evidence collected to develop a measure of engagement employing a more varied set of indicators. This also raises the question of whether an alternative approach to measuring engagement with science would produce a different typology structure. Furthering knowledge in this direction could be informative concerning the socio-demographic distribution of the population across forms of engagement. Alternative measures might result in a less skewed and more dispersed socio-demographic distribution across forms of engagement, which would be an important step towards a more nuanced representation of engagement with science across diverse populations. In the realm of methodological limitations, as discussed in Chapter 3, the quantitative studies included in this dissertation do not address the cross-country variations of the mechanisms investigated, but only present general results for the sample of European countries considered, net of their singular influence. This decision prioritizes general trends over the role of contextual influences, which limits the informative power of the analyses by leaving some cultural variation uncovered. Applying different prioritization choices to the available data would have been able to uncover further contextual insights on Europeans' engagement with science and the role of science attitudes.

7.5 Future directions

The insights of this dissertation and the discussions that they generate motivate further research. A possible continuation of the proposition to adopt a more inclusive approach towards alternative forms of engagement with science, would be to investigate the engagement potential of informal, personal, relational, and practical engagement activities, and their relationship with formal ways of engaging. I provide initial evidence of this relationship, although a more comprehensive analysis is encouraged. This relationship has been already applied in studies of engagement and produced fruitful insights (Marres, 2016; Carrel, 2023; Kaszaki, 2023). In addition, the demarcation between activities that are, and are not, considered engagement with science is at times represented by the visibility of a scientific institution. This is the case for birdwatching or mushroom picking, which are generally considered hobbies but which, when they involve the collection of data for scientific purposes, turn into activities of citizen science. Thus, it would be valuable to investigate the role of this visibility for the science-related experience of members of the public engaging in such activities. In the interviews, I observed that awareness of being engaged in a science related activity can be a driver for positive science perception, but it can also generate feelings of inferiority and avoidance of science. Investigating the role of science communicators and awareness in the process of engagement with science could reveal important insights to better direct efforts of science communication. Moreover, studying the relationship between informal engagement with science and science attitudes might generate further knowledge on the habits and the opinions of the *disengaged* population.

Building on insights from this investigation and the implications that different methodological choices had for the overall study, I identify here two specific methodological choices as possible avenues for future research on public engagement with science. The first research direction I suggest is a wide qualitative analysis based on focus groups. Discussions among members of the population representing different social strata might contribute to uncovering shared experiences and understandings of engagement with science. Homogeneous and heterogenous focus groups may be used to contribute to the development of new indicators of public engagement with science (although with caveats Macknight & Medvecky, 2021), to be tested in a subsequent survey experiment. Given the widespread use of surveys in academic research and policy-making it is important to strive towards developing indicators that are representative and inclusive.

A second and somewhat different research direction I suggest is a quantitative study putting more emphasis on the concepts of deference towards authority and technocratic tolerance. The role of scientific and democratic institutions proved to be a major element in the interviewees' experiences, perceptions, and opinions of public engagement with science, which warrants further investigation. Among the design choices that could produce further insights on this is a survey experiment based on the results from article B. Drawing from this study would allow employing well-crafted indicators for the mechanisms concerning engagement, attitudes, and socio-economic status to be tested.

Finally, it would be informative to take the context for public engagement with science into consideration and analyze the relationship between engagement and democratic preferences across liberal democratic societies – where the public is encouraged and expected, to different extents, to take part in policymaking. An informed and in-depth investigation of the specificities of different countries, when it comes to public engagement with science, would contribute to identifying a set of relevant contextual characteristics affecting public dispositions to engagement with science, or vice versa. Of particular interest could be a comparison of a small set of countries as case studies, which would allow the researcher to identify country specificities that might be related to engagement with science. Different regions of Europe, or the world, may exhibit local patterns of engagement due to historical, cultural, political, or educational factors and understanding these interactions might contribute to existing evidence (e.g. Bauer et al., 2012; Makarovs & Achterberg, 2017; 2018) while informing policy making. A comprehensive analysis of the interaction between individual and contextual engagement dimensions has been beyond the main aims of the current dissertation. However, future research on these lines can contribute to our understanding of social dynamics affecting the reception of scientific knowledge and direct interventions aimed at promoting scientifically engaged and inclusive societies.

7.6 Concluding remarks

At the beginning of this chapter, I set out to explore *how socio-demographic characteristics interact with public engagement with science?* I motivated this interest by outlining academic debates on public engagement with science, pointing to the need to further include marginalized members of society in science discourse, while simultaneously addressing underlining structural inequalities. The empirical analyses composing the dissertation have been guided by three sub-questions tackling the main research interest from three different points of view. These have made the study evolve and change its scope. Indeed, at this point it is apparent that the final shape of this dissertation detaches itself from its original aim. The evidence gathered from describing the public through their engagement habits (RQ1) led to questioning the role of attitudes towards science for engagement (RQ2), which generated curiosity for stepping outside pre-defined categories and observing engagement with science from the personal point of view of lay people (RQ3). These empirical analyses cover the ground surrounding to the goal of observing the interaction between socio-demographic characteristics and public engagement with science, which can be considered the overall motivation and underlying direction for this dissertation. From initially adhering the common modus operandi of looking for reasons for (dis)engagement among the public itself, to turning towards consulting the public as lay expert on evidence and reasonings behind (dis)engagement, I contribute to the literature by addressing a wider question: *who engages with science and what is science engagement*?

This project is not aimed at producing practical applications or recommendations for policy development, rather it aims at providing empirical evidence for the academic discussion on definitions, goals and motives for (dis)engagement. Nevertheless, I end this concluding section with three implications that the results of this study have for addressing public (dis)engagement with science within policymaking and academia. The first concerns the value of recognizing a broader range of (dis)engagement possibilities, beyond the established categorizations. This approach focuses on the necessity of a detailed understanding of disengagement, not adequately described by current indicators. It also emphasizes the importance of gaining further insights into science-related activities performed by disadvantaged groups of the population, often considered disengaged. The second implication regards the utility of an explorative approach to engagement, to account for the multidimensionality of (dis)engagement and reformulate its overarching goals. Recognition of the heterogeneous nature of (dis)engagement prompts a comprehensive understanding of the goals of science communication, to include serving individuals as human beings, besides citizens, for whom science can be personally and practically beneficial. Finally, public engagement in deliberative activities is fundamental for the functioning of modern democracies. Thus, at the same time it is crucial to ensure that diverse social groups have equal possibilities to access engagement activities of deliberative nature. However, this emphasis should not absolve governmental and scientific institutions of their inherent responsibilities in representation. While efforts towards expanding public engagement in decision-making or science co-creation are necessary, they must be complemented by parallel efforts to fulfill the responsibility of ensuring that all voices are heard and considered in the broader governance discourse, including those of the disengaged. Balancing these objectives is essential for a truly inclusive and representative democratic and scientific processes.

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English Summary

In modern social contexts in which science and technology are pervasive in multiple aspects of individual and social life, the need to understand how the relationship between science and the public is constructed assumes a crucial role. This relevance is mirrored in the considerable increase in attention on this subject and its practical applications among academic research and policy making. Nevertheless, empirical research on the diverse patterns of public engagement with science among different social groups is still underdeveloped. This project aims at delivering empirical evidence on the mechanisms that link public and science in practice and inform innovative strategies to enhance communication, accessibility and inclusivity. I approach this topic by avoiding a conception of the public as deficient with respect to science knowledge, understanding, or trust. Instead, this project adopts an open and exploratory approach that holds accountable actors from three core constructs influencing this relationship: individuals, science, and society. By engaging with theoretical concepts from sociology, political science, science communication and science and technology studies, I aim at understanding *how do socio-demographic characteristics interact with public engagement with science*. Through this study I address various core challenges of this field such as the restricted set of activities through which public engagement with science is traditionally conceptualized, the emphasis on deliberation over others forms and aims of engagement, and the limited socio-demographic diversity of the engaged public.

I address these challenges in three empirical studies through diverse methodological approaches. In the first study I employ data from the Eurobarometer survey to create a typology of forms of engagement of the European public. Through an extensive set of established engagement indicators, I observe that almost half of the European population can be considered disengaged and belongs to disadvantaged socio-demographic social groups. In the second study, I employ the same dataset to observe the mediating role of attitudes towards science in the relationship between socio-economic status and engagement with science. Results show that science attitudes are not able to explain the socio-economic gap in engagement, although authority deference shows a puzzling trend. For what concerns the extent to which members of the public defer to experts when it comes to science decision making, this is lower among disadvantaged socio-economic groups of the population, but it not followed by active personal engagement with science. In the last empirical study, I combine and deepen evidence from the first two studies through self-collected interviews with members of the population located in England and with

socio-demographic characteristics generally associated with lower levels of engagement with science. Through the analysis of informants' experiences and perspectives, I observe that engagement with science has more nuances than is allowed for in contemporary approaches to science engagement. When asked to reflect on established practices of engagement, informants do not perceive themselves as engaged, but when they are asked to mention the instances in which they recognize science in their daily lives a wide array of more and less formal activities emerges.

Reading these empirical results in concert highlights the contribution of this dissertation. By measuring engagement through established and formalized indicators, I observe that half of the European population can be described as disengaged. At the same time, openly exploring informants' practices reveals a more nuanced image. Established and formalized indicators of engagement with science produce an undetailed representation of the disengaged public which hinders our ability to comprehend the nature of disengagement and the instances in which it may result in problematic attitudes. Moreover, I observe that people from disadvantaged social groups can be described as disengaged, but at the same time they seem more likely to engage with science through alternative and less formalized activities. Thus, a more detailed understanding of disengagement could also improve social diversity in the representation of engagement. In addition to representation, a detailed and socially just measurement of engagement might allow further understanding of the (dis)engaged (dis)advantaged population. Adopting such an exploratory approach to engagement with science implies wider vision about the goals of engagement. Among the aims usually associated with public engagement with science there are democratizing science and society, enhancing access to science, and increasing legitimacy and acceptance of science. Nevertheless, based on the evidence collected I argue for the value of opening these goals to include the enhancement of individuals' personal lives. Complementing the understanding of members of the public as *citizens* with that of *human beings* who can personally benefit from engagement with science might lead to new fruitful approaches to science communication. Finally, existing research interprets the discrepancy that I observed among disadvantaged social groups – having low levels of deference towards experts in science decision making and low levels of personal engagement – to indicate a democratic deficit. This deficit, is argued, reflects a lack of opportunities for these individuals to translate their democratic aspirations into action. In addition to this perspective, insights from the qualitative study suggest that this discrepancy might also indicate a call for social accountability and transparency of institutions. Thus, while public participation in deliberative activities remains at the core of modern democracies and efforts should be made to ensure that diverse social groups have access to such initiatives, this should not absolve democratic institutions from their inherent responsibilities. Efforts towards expanding deliberative engagement should be balanced with ensuring the inclusion in the governance processes of all voices, including the disadvantaged, and disengaged.

Dansk Resumé

I det moderne samfund, hvor videnskab og teknologi er gennemgribende i flere aspekter af individuelle liv og samfundslivet, er det nødvendigt at forstå forholdet mellem videnskab og offentlighed. Dette afspejles i den betydelige stigning i opmærksomheden dette emne, og dets praktiske anvendelser, har modtaget i forskning såvel som i politik. Ikke desto mindre er empirisk forskning i mønstre i, hvordan offentligheden engagerer sig i videnskab på tværs af sociale grupper stadig underudviklet. Dette projekt har til formål at levere en empirisk base til at undersøge de mekanismer, der forbinder offentligheden med videnskaben i praksis, og informere innovative strategier til at forbedre kommunikation, tilgængelighed og inklusion. I tilgangen til dette emne efterstræber jeg at undgå en opfattelse af offentligheden som mangelfuld med hensyn til videnskabelig viden, forståelse, eller tillid. I stedet anvender dette projekt en åben og eksplorativ tilgang, hvor ansvaret placeres hos tre kerneaktører: individer, videnskab og samfund. Ved at inddrage teori fra sociologi, statskundskab, videnskabskommunikation og videnskabs- og teknologistudier sigter jeg mod at forstå, *hvordan sociodemografiske karakteristika interagerer med offentlighedens engagement i videnskab*. Gennem projektet tager jeg fat på forskellige centrale udfordringer inden for forskningsfeltet såsom det begrænsede sæt af aktiviteter, hvorigennem offentlighedens engagement i videnskab traditionelt konceptualiseres, vægten på deliberation frem for andre former og mål for engagement, og den begrænsede sociodemografiske mangfoldighed i den engagerede offentlighed.

Jeg adresserer disse udfordringer i tre empiriske studier med forskellige metodiske tilgange. I det første studie anvender jeg data fra Eurobarometerspørgeskemaet til at skabe en typologi over former for engagement i den europæiske offentlighed. Gennem et omfattende sæt af etablerede engagementsindikatorer observerer jeg, at næsten halvdelen af den europæiske befolkning kan betragtes som uengageret og tilhører ugunstigt stillede sociodemografiske grupper. I det andet studie anvender jeg det samme datasæt til at observere den medierende rolle, som holdninger til videnskab spiller i forholdet mellem socioøkonomisk status og engagement i videnskab. Resultaterne viser, at holdninger til videnskab ikke er i stand til at kompensere for den socioøkonomiske forskel i engagement, selvom respekt over for autoriteter udviser uklare tendens. I forhold til borgernes hang til at underlægge sig eksperter, når det gælder videnskabelig beslutningstagning, er der lavere tendens til dette blandt dårligt stillede socioøkonomiske grupper, men det følges ikke af aktivt personligt engagement i videnskab. I det sidste studie kombinerer og uddyber jeg beviserne fra de to første undersøgelser gennem selvindsamlede interviews

med borgere i England med sociodemografiske karakteristika, der generelt er forbundet med lavere niveauer af engagement i videnskab. Gennem analysen af informanternes erfaringer og perspektiver observerer jeg, at engagement i videnskab har flere nuancer, end der er plads til i nuværende tilgange til dette spørgsmål/emne. Når de bliver bedt om at reflektere over etablerede praksisser for engagement, opfatter informanterne ikke sig selv som engagerede, men når de bliver bedt om at nævne de tilfælde hvor de genkender videnskab i deres daglige liv, dukker der en bred vifte af mere og mindre formelle aktiviteter op.

I fællesskab fremhæver disse resultater denne afhandlings bidrag. Ved at måle engagement gennem etablerede og formaliserede indikatorer observerer jeg, at halvdelen af den europæiske befolkning kan beskrives som uengageret. Samtidig afslører en åben udforskning af informanternes praksis et mere nuanceret billede. Etablerede og formaliserede indikatorer for engagement i videnskab producerer en udetaljeret repræsentation af den uengagerede offentlighed, som hindrer vores evne til at forstå karakteren af denne ligegyldighed og de tilfælde, hvor den kan resultere i problematiske holdninger. Desuden observerer jeg, at folk fra dårligt stillede sociale grupper kan beskrives som uengagerede, men på samme tid synes de mere tilbøjelige til at engagere sig i videnskab gennem alternative og mindre formaliserede aktiviteter. Således kunne en mere detaljeret forståelse af manglende engagement også forbedre den sociale diversitet i repræsentationen af engagement. Ud over repræsentation kan et detaljeret og socialt retfærdig mål på engagement give mulighed for yderligere forståelse af den (ikke-)engagerede (u)begunstigede befolkning. En sådan eksplorativ tilgang til engagement i videnskab indebærer en bredere vision om målene for engagement. Blandt de mål, der normalt forbindes med offentligt engagement i videnskab, er at engagere befolkningen i videnskab for at demokratisere videnskaben og samfundet, forbedre adgangen til videnskab og øge legitimiteten og accepten af videnskab. Baseret på den indsamlede dokumentation argumenterer jeg dog for værdien af at udvide disse mål til også at omfatte forbedring af den enkeltes personlige liv. Der kan muligvis følge nye frugtbare tilgange til videnskabskommunikation i kølvandet på erkendelsen af, at offentligheden ikke bare består af borgere, men også af mennesker. Endelig fortolker eksisterende forskning den uoverensstemmelse, som jeg observerede blandt dårligt stillede sociale grupper - med lave niveauer af respekt over for eksperter i videnskabelig beslutningstagning og lave niveauer af personligt engagement - til at indikere et demokratisk underskud. Dette underskud, hævdes det, afspejler en mangel på muligheder for disse individer til at omsætte deres demokratiske forhåbninger til handling. Ud over dette perspektiv antyder indsigter fra den kvalitative undersøgelse, at denne uoverensstemmelse også kan indikere en opfordring til social ansvarlighed og gennemsigtighed i institutioner. Selvom offentlig deltagelse i deliberative aktiviteter fortsat er kernen i moderne demokratier, og der bør gøres en indsats for at sikre, at forskellige sociale grupper har adgang til sådanne initiativer, bør dette ikke fritage demokratiske institutioner fra deres iboende ansvar. Bestræbelserne på at udvide deliberativt engagement bør afbalanceres ved at sikre, at alle stemmer, herunder de dårligt stillede og uengagerede, inkluderes i styringsprocesserne.

Sintesi in italiano

Nei moderni contesti sociali in cui la scienza e la tecnologia sono pervasive in molteplici aspetti della vita individuale e sociale, la necessità di comprendere come viene costruito il rapporto tra scienza e pubblico assume un ruolo cruciale. Questa rilevanza si riflette nel considerevole aumento dell'attenzione su questo tema e sulle sue applicazioni pratiche nella ricerca accademica e nella politica pubblica. Tuttavia, la ricerca empirica sui diversi modelli di coinvolgimento pubblico con la scienza tra i vari gruppi sociali è ancora poco sviluppata. Questo progetto mira a fornire dati empirici sui meccanismi che collegano pubblico e scienza nella pratica e a informare strategie innovative per migliorare la comunicazione, l'accessibilità e l'inclusività. Affronto questo tema evitando una concezione del pubblico come carente in termini di conoscenza, comprensione o fiducia nella scienza. Al contrario, questo progetto adotta un approccio aperto ed esplorativo che considera responsabili gli attori di tre costrutti fondamentali che influenzano questa relazione: gli individui, la scienza e la società. Utilizzando concetti teorici provenienti dalla sociologia, dalla scienza politica, dalla comunicazione scientifica e dagli studi sulla scienza e la tecnologia, mi propongo di capire come le caratteristiche sociodemografiche interagiscono con il coinvolgimento del pubblico nella scienza. Attraverso questo studio affronto diverse sfide fondamentali di questo campo, come l'insieme ristretto di attività attraverso cui il coinvolgimento del pubblico con la scienza è tradizionalmente concettualizzato, l'enfasi sulla deliberazione rispetto ad altre forme e obiettivi del coinvolgimento e la limitata diversità sociodemografica del pubblico coinvolto.

Affronto queste sfide in tre studi empirici attraverso approcci metodologici diversi. Nel primo studio utilizzo i dati dell'indagine Eurobarometro per creare una tipologia di forme di coinvolgimento del pubblico europeo. Attraverso una serie di indicatori di coinvolgimento consolidati, osservo che quasi la metà della popolazione europea può essere considerata “non coinvolta” e appartiene a gruppi sociodemografici svantaggiati. Nel secondo studio, utilizzo la stessa base di dati per osservare il ruolo di mediazione degli atteggiamenti verso la scienza nella relazione tra status socioeconomico e coinvolgimento nella scienza. I risultati mostrano che gli atteggiamenti verso la scienza non sono in grado di spiegare il divario socioeconomico nell'coinvolgimento, anche se la deferenza dell'autorità mostra tendenze enigmatiche. Infatti, la misura in cui i membri del pubblico si rimettono agli esperti quando si tratta di prendere decisioni in campo scientifico è più bassa tra i gruppi socioeconomici svantaggiati della popolazione, ma non è seguita da un coinvolgimento personale attivo con la scienza. Nel terzo studio empirico, combino e approfondisco le evidenze dei primi due studi attraverso interviste a membri della popolazione residenti in Inghilterra e con caratteristiche sociodemografiche generalmente associate a livelli inferiori di coinvolgimento con la scienza. Attraverso l'analisi delle esperienze e delle prospettive degli informatori, osservo che il coinvolgimento con la scienza ha molte più sfumature di quelle previste dagli approcci contemporanei. Quando si chiede loro di riflettere sulle pratiche consolidate di coinvolgimento, gli informatori non si percepiscono come attivi, ma quando si chiede loro di menzionare i casi in cui riconoscono la scienza nella loro vita quotidiana, emerge un'ampia gamma di attività più e meno formali.

La lettura congiunta di questi risultati empirici evidenzia il contributo di questa tesi. Misurando il coinvolgimento attraverso indicatori stabiliti e formalizzati, osservo che metà della popolazione europea può essere descritta come "non coinvolta". Allo stesso tempo, l'esplorazione aperta delle pratiche degli informatori rivela un'immagine più sfumata. Gli indicatori stabiliti e formalizzati del coinvolgimento con la scienza producono una rappresentazione non dettagliata del pubblico non coinvolto, che ostacola la nostra capacità di comprenderne la natura e di individuare i casi in cui può sfociare in atteggiamenti problematici. Inoltre, osservo che le persone appartenenti a gruppi sociali svantaggiati possono essere descritte come non coinvolte, ma allo stesso tempo sembrano più propense a interagire con la scienza attraverso attività alternative e meno formalizzate. Pertanto, una comprensione più dettagliata del mancato coinvolgimento potrebbe anche migliorare la diversità sociale nella rappresentazione di questo. Oltre alla rappresentazione, una misurazione dettagliata e socialmente corretta del coinvolgimento potrebbe consentire un'ulteriore comprensione della popolazione (non) coinvolta. L'adozione di un tale approccio esplorativo verso il coinvolgimento con la scienza implica una visione più ampia degli obiettivi desiderati. Tra gli obiettivi solitamente associati al coinvolgimento del pubblico con la scienza vi sono democratizzare la scienza e la società, migliorare l'accesso alla scienza e aumentare la legittimità e l'accettazione della scienza. Tuttavia, sulla base delle prove raccolte, sostengo il valore dell'apertura di questi obiettivi per includere il miglioramento della vita personale degli individui. Completare la comprensione dei membri del pubblico come cittadini con quella di esseri umani che possono beneficiare personalmente di un coinvolgimento con la scienza potrebbe portare a nuovi approcci fruttuosi alla comunicazione scientifica. Infine, la ricerca esistente interpreta la discrepanza che ho osservato tra i gruppi sociali svantaggiati - che hanno meno deferenza verso gli esperti nei processi decisionali in campo scientifico e meno coinvolgimento personale - come indice di un deficit democratico. Questo deficit, si sostiene, riflette la mancanza di opportunità per questi individui di tradurre in azione le loro aspirazioni democratiche. Oltre a questa prospettiva, le intuizioni dello studio qualitativo suggeriscono che questa discrepanza potrebbe anche indicare una richiesta di responsabilità sociale e di trasparenza delle istituzioni. Così, mentre la partecipazione pubblica alle attività deliberative rimane al centro delle democrazie moderne e si dovrebbero compiere sforzi per garantire che gruppi sociali diversi abbiano accesso a tali iniziative, ciò non dovrebbe esimere le istituzioni democratiche dalle loro responsabilità intrinseche. Gli sforzi per espandere il coinvolgimento deliberativo dovrebbero essere bilanciati con la garanzia dell'inclusione nei processi di governance di tutte le voci, comprese quelle svantaggiate e poco coinvolte.

Appendix A
Participant Information Sheet and Consent Form from Article C

DANISH CENTRE FOR STUDIES IN RESEARCH AND RESEARCH POLICY

DEPARTMENT OF POLITICAL SCIENCE
AARHUS UNIVERSITY

Participant Information

Department of Political Science

Lucilla Federica Losi
PhD Fellow

E-mail: lucilla.losi@ps.au.dk
Web:
au.dk/en/lucilla.losi@ps

Sender's CVR no.: 31119103

Dear participant,

You receive this information form as you have agreed to participate in the interview study connected to my PhD dissertation about the relationship between science and the public. This document includes all the information you need to be aware of before giving your full con-sent to take part in the study. Please, read carefully before our meeting. I am available for any clarification and my contact details follow below.

Primary Investigator (P.I.): Lucilla Losi, Danish Centre for Studies in Research and Research Policy, Aarhus University, Denmark. E-mail: lucilla.losi@ps.au.dk.

Research project objectives: This data collection is part of my PhD dissertation exploring the relationship between science and the public. Through interviews with non-scientists, I wish to understand how they perceive science and the role it has in their everyday life. The questions I will ask concern people's idea of science, their relationship and contact with science, and their evaluation of it. Thus, I am not interested in evaluating the knowledge or levels of participation, but rather I wish to be informed about their views and experiences.

Funding: this study is funded by the Social Science and Business PhD programme at Aarhus University, Denmark.

Participants recruitment: Participants are contacted by the P.I. on social media platforms or flyers hanged in public libraries or other venues. Participants will then be asked to kindly suggest other potential participants among their social network (not family members).

Method: This study consists of face-to-face in-depth semi-structured qualitative interviews and the P.I. (Lucilla Losi) will be the only person present during the interviews. The interview will take place in a location in agreement between the P.I. and the participants. Upon completion of the interview, the participant will receive a 10£-worth compensation.

Expected risks: the topic of the study and the methodology are not expected to constitute elements of risk for the participants. Some question might be sensitive for some respondents, but the P.I. will do her best to create a comfortable and welcoming environment. Furthermore, participation and completion of the interview are fully voluntary, the interview can be interrupted at any time, disclosure of personal information is discretionary, and questions can be skipped.

Beneficiaries of the study: the results of this study will be employed to write a research article including policy recommendations on how to make science engagement practice more inclusive and socially just. So, ultimately, the respondents are expected to benefit from increased social representation and inclusion in science-society relations.

Communication of the results of the study: if the participants are interested, the research article(s) elaborated on the basis of the results of this study will be forwarded by the author.

Sensitive personal data protection: interviews will be transcribed by student assistants employed by Aarhus University, Denmark. Only the author will own personal sensitive information and will take care of changing the names and any reference to the identity of the participants upon publication of the results. Direct quotes from the interview might be used and in that case the owner of the quote (participant) will be referred to by a pseudonym, age and profession. Data will be stored on Aarhus University official secured drives and the recordings will be destroyed upon completion of the transcription.

Withdrawing from the study: participation in the study is fully voluntary. After giving the consent, participants are still able to withdraw this consent at any time during and after the interview without the need of providing an explanation. If they do so during the interview, the recording will stop and will be deleted, and the material will not be employed in the analysis. If the consent is withdrawn after the interview is over, the recording will be destroyed with the transcription (if already transcribed) and the corresponding material will not be used in the analysis.

Opportunity to view the transcription: upon request by the participants, the author will provide the transcribed interview and quotes. On rare occasions, the author might contact the participants after the interview is over for clarification purposes.

Debriefing: upon request by the participants, the author is available for follow-up meetings.

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Participant Information about processing of personal data

The data controller	**Aarhus University** **Nordre Ringgade 1** **DK-8000 Aarhus C** **CVR no.: 31119103** is the data controller responsible for the processing of personal data in the research project. The research project is headed by Lucilla Losi who can be contacted at lucilla.losi@ps.au.dk, Danish Centre for Studies in Research and Research Policy, Department of Political Science, Bartholins Allé 7, 8000 Aarhus DK.
Data protection officer at Aarhus University	Søren Broberg Nielsen Data protection officer/DPO dpo@au.dk
Title of the research project	"Beyond deliberation. Exploring people's perception and experience of science" - Public perception of science.
The purpose of the project and of processing your personal data	This data collection is part of my PhD dissertation exploring the relationship between science and the public. Through interviews with non-scientists, I wish to understand how they perceive science and the role it has in their everyday life. The questions I will ask concern people's idea of science, their relationship and contact with science, and their evaluation of it. Thus, I am not interested in evaluating the knowledge or levels of participation, but rather I wish to be informed about their views and experiences. The data collected will be employed in the production of research articles and will be part of the final PhD dissertation.
Which personal data will be processed in the project?	The project will process the following information about you as a participant: ☒Name (this information will not appear in related pubblications) ☒Age ☒Gender ☒Education ☒Employment ☒Area of living ☒Nationality ☒Perception and experience of science – content of the interview
For how long do we store your other personal data?	At present, we cannot say for how long we will be processing your personal data. Your personal data will be processed by Aarhus University in a personally identifiable form for as long as required by the research purpose and the rules on storage according to responsible conduct of research. When I no longer need your personal data for processing, the data will be anonymised, transferred to the Danish National Archives or erased.
Will personal data be made available or disclosed to others, e.g. researchers at other universities?	☒Your personal data collected for the project will not be disclosed to others.
The personal data has been obtained:	☒From you

We are entitled to process your personal data pursuant to the rules of the General Data Protection Regulation and the Danish Data Protection Act.	☒Article 6(1)(a) and Article 9(2)(a) entitle Aarhus University to process sensitive personal data about you on the basis of your consent.
We are obligated to inform you about the rules that apply to our work with your personal data.	
Participants' rights under the General Data Protection Regulation	You have the following rights if Aarhus University processes your personal data: • Right of access - you have the right to see the personal data concerning you that is processed by the data controller and to receive various information concerning the processing. • Right to rectification - you have the right to have inaccurate/incorrect personal data about you corrected. • Right to erasure or the "right to be forgotten". • Right to restriction of processing. • Right to data portability - in some cases, you have the right to receive your personal data and to request that the personal data be transferred from one data controller to another. • Right of objection - you have the right to object to the otherwise lawful processing of your personal data. • Right not to be subject to an automatic decision based solely on automated processing, including profiling. Note that your rights may be limited by other legislation or be subject to exemptions, e.g. in relation to research and the exercising of public authority.
Complaints	If you wish to complain about the processing of your personal data, you can do so by contacting the supervisory authority: **The Danish Data Protection Agency** dt@datatilsynet.dk **Carl** **Jacobsens Vej 35** **DK-2500 Valby**

AARHUS BSS
DANISH CENTRE FOR STUDIES IN RESEARCH AND RESEARCH POLICY
DEPARTMENT OF POLITICAL SCIENCE
AARHUS UNIVERSITY

Consent to processing of personal data

In connection to your participation in the research project on perception and experiences of science by a researcher from Aarhus University (Denmark), you are required to sign this consent form to collection and use of personal data for academic research purposes and in compliance with the rules of the General Data Protection Regulation (GDPR). Read more about the project and the processing of your personal data in the information form.

Primary investigator: Lucilla Losi, Danish Centre for Studies in Research and Research Policy, Aarhus University, Denmark. E-mail: lucilla.losi@ps.au.dk.

I hereby consent to the aforementioned researcher's processing of data concerning me in connection with her degree programme at Aarhus University (Denmark). I declare that:

- I have read and understood the "participant information" forms and had enough time to ask questions.
- I know that my participation is fully voluntary, and I can retract my consent and discontinue the study at any point without the need to provide an explanation.
- My personal data will be used in the aforementioned project. Therefore, I give my consent for:
- The storing and processing of my data in the project and related research articles.
- My data may be disclosed to Aarhus University (Denmark) and to any external as-sistant in connection with transcription purposes.
- My data may be disclosed to Aarhus University (Denmark) and to any external coexaminer in connection with supervision and assessment.
- My data may be published in a pseudonymized form in connection with the publication of the project and related research articles.

The consent is voluntary, and you may at any time withdraw your consent to the processing and storing of your personal data. You may do this by contacting Lucilla Losi at this email address: lucilla.losi@ps.au.dk

Withdrawing your consent will not affect the lawfulness of my work with your personal data in the project before your withdrawal. Your personal data will therefore continue to be included in the work carried out in the project before you withdrew your consent.

Name: ______________________ Date: _______________________

Signature: _______________

Appendix B
Study Advertisement from Article C

STUDY: PUBLIC PERCEPTION OF SCIENCE

PARTICIPANTS NEEDED

If you are…

- Based in xxx
- 18yo or older
- Not a student
- Not a scientist

Scan the QR code!

Hi!
I am looking for participants in a study about **public experience** of **science** in everyday life.
Not an assessment, I am only interested in learning **what you think**!
Will you help me?

50min face-to-face interview

Location of your choice

10£ grocery voucher

This study has been approved by the Research Ethics Board of Aarhus University (Denmark)

AARHUS UNIVERSITY