Pocket science.
The praxeological dimension of scientific culture

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Ciemat

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
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Publication available in catalog of official publications

NIPO: 832-22-001-2

Edition and Publication:
Editorial CIEMAT
Avda. Complutense, 40 28040-MADRID
e-mail: editorial@ciemat.es
Editorial news

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INTRODUCTION: SCIENTIFIC CULTURE IN TIMES OF GLOBAL CRISIS

Crisis is a time of great danger, difficulty or doubt in which problems must be solved, or important decisions must be made. Undoubtedly human beings, as a species, currently have to face multiple and serious crises. It is probably not an unprecedented situation. Throughout their long history on this planet, human beings have had to face periods of crisis that have left their mark. Perhaps what makes the present moment unique is that crises are multiple and all of them pose a very serious threat. We are immersed in an environmental crisis, suffering a global pandemic seeming not to give truce, and it is also extensive the list of social maladjustments.

Multiple crises, and their multiple facets, exacerbate structural problems. The global coronavirus pandemic is posing enormous challenges to societies and political systems. From the beginning, it was clear that human suffering - deaths and changes in the lives of millions of people - would have important economic, social and institutional consequences. Furthermore, over time it has become more explicit that, although it affects all segments of the population, both the pandemic and its aftermath are particularly harmful for those social groups in vulnerable situations, including the poor, the elderly, the disabled, youth or minority groups. Public policies, including scientific-technological ones, must manage their immediate and long-term consequences, including the increase in inequality, unemployment, poverty and social exclusion.

The scenario turns out more complicated because we live in a time in which institutional and political representation are also in a crisis that is placing political systems and democracy at important crossroads. Although it probably cannot be said that there is a political and democratic crisis because there is no evidence of a decline in public commitment to the principles of democracy, there are certainly worrying signs of it, especially in certain circumstances. Political radicalization, migratory crises, the virulence of political debates, tolerance for information censorship or the persecution of the displaced, remind us that the democratic balance is always delicate. Anyway, there certainly is evidence that political support is waning.

We have never had so much information available, but surely we have not been so misinformed either. Probably because the relationship between quantity and quality of information is best represented by an inverted U, like the Jerkes-Dobson law that relates performance and arousal: performance improves with arousal, but only up to a certain level, once reached, performance deteriorates. We now have "tons" of information at our disposal, but confirmation bias (both "natural" and technology-induced) makes us insensitive to information that we don't want to know. There is a combination of good quality, valid and reliable, but also false, misleading and malicious information. Both are said to have the same "power" to reach people. But the confirmation bias makes this consideration not true in the strict sense, so people tend to see only a small part of the information available, often of low quality or misleading.

Simultaneously, social reactions and relationships are increasingly determined by polarization. It is as if we now only see the social "world" in black and white. According to the psychologist Aaron Beck, people develop cognitive schemas that they use in a stable way to understand and interpret reality. Cognitive distortions are errors in information processing that lead us to commit biases when interpreting that reality, which interferes with our mental health (Beck, 1963). This model can also be used to interpret the current social context. From this perspective, the tendency of society to polarize around any topic or debate can be explained, at least partially, by the biases produced by cognitive distortions, which would also be affecting “social health”.

Beck defined 10 cognitive distortions: 1) selective abstraction (the tendency to pay attention to only one aspect or detail of reality); 2) dichotomous thinking (tendency to value events in a polarized way: good / bad, black / white, all / nothing); 3) arbitrary inference (tendency to draw conclusions from a situation that are not supported by the facts); 4) overgeneralization (tendency to draw a general conclusion from a particular fact); 5) magnification and minimization (tendency to exaggerate the negative of a situation, an event or a quality and to minimize the positive); 6) personalization (tendency to relate external events to oneself when there is no evidence to do so); 7) catastrophic vision (tendency to think that the worst will always happen); 8) you should (keep rigid and demanding rules about how things should be); 9) global labels (valuing things by global labels regardless of nuances); and 10) guilt (tendency to attribute all responsibility for events to oneself or others, ignoring other contributing factors). Many of them can help explain current social maladjustments.

Social media have become the perfect tool for those looking to profit from polarization. Historian Steven Forti in the book *Extrema derecha 2.0. Qué es y cómo combatirla* (“Far right 2.0. What is it and how to combat it”) points that social media offer legal and acceptable methods, and others that are not, such as fake accounts, bots (automatic accounts) or troll farms, which are small companies or government departments that try to impose their speech, often riddled with hatred and falsehoods. Some of these actions are literally called *shitstorms*, consisting of highly virulent digital lynchings. These strategies are based on the fact that the more hateful the messages are, the more viral they become.

On the other hand, the management of people's daily lives depends on science and technology at levels never before achieved. Most personal and political decisions involve addressing issues related in one way or another to science and technology. But the complexity of scientific and technological developments together with the large quantity and easy access to information related to science, from different sources and extremely variable in terms of its reliability and quality, faces citizens with new and constant challenges. In this context, it would be desirable that citizens' choices and decisions were grounded on the best available scientific knowledge. But the characteristics of these challenges are inevitably associated with controversies and uncertainties, and this is something difficult to manage. In parallel, scientific knowledge is vast, often uncertain and complex, and this makes it impossible for a single individual to acquire and fully understand it. To manage this complexity, societies are characterized by a "cognitive division of labour" in such a way that knowledge is broken down into different disciplines that are represented by specialized experts.

Knowledge is unevenly distributed among members of a society and therefore each individual is a lay person in most of their domains.

Furthermore, it cannot be said that there is a public rejection of science as a whole, but the relationship between science and society is not as fluid as it should be if we take into account individuals and society's dependence on scientific and technological developments. On the other hand, a serious problem arises when the ease of processing popularized descriptions of scientific and technological developments causes people to underestimate their dependence on experts. It also generates the easiness effect, i.e., makes them overlook the limitations of their capacities to evaluate the veracity, relevance, and sufficiency of the information they receive (Scharrer et al., 2017). This effect can cause the rejection of a technology useful for society, but also can provoke abuses or bad uses. A good example is the problem of bacterial resistance due to the bad use and incorrect demand of antibiotics or the rejection of vaccination.

Under these coordinates, the promotion of scientific culture responds to the objective of boosting a social voice of quality and promote a constructive dialogue between science and society. Although scientific (science) culture is understood in a diverse array of ways and there is no a unified theory about it, traditionally this concept includes scientific knowledge, values, interests and attitudes of people regarding science. But it also takes into account the way these elements interact and influence decision making in issues involving science, both in daily life and in extraordinary circumstances.

This is the framing from which this volume addresses the topic of the praxeological dimension of scientific culture. The Merriam-Webster dictionary defines praxeology as the study of human action and behaviour. The term, with Greek roots (for πραξις, praxis, action, and λόγος, logos, speech), has a current use that seems to come from the French *praxéologie* in the late 19th and early 20th centuries. The French philosopher and social theorist Alfred Espinas used the term in *Les origines de la technologie* (1897) to refer to the general principles of global human activity (which in the field of manufacturing would be Technology, in capitals), approximating thus its etymology to the current field of operational research, systems theory or decision theory (Mitcham, 1994 p. 33). The spreading and contemporary meaning of the term is indebted to Ludwig von Mises and the Austrian school of economics, who tried to base economics on praxeology, understood not as a field of empirical study but as the deduction of the postulates of economics from the analysis a priori of the basic principles of human action.

This book presents some contributions developed in the framework of the coordinated research project: “Praxeology of Scientific Culture”. It is composed of two subprojects: “Praxeology of Scientific culture: Concept and dimensions” (Reference MINECO-18-FFI2017-82217-C2-1-P) and “Praxeology of Scientific culture: Evaluation and measurement (Reference MINECO-18-FFI2017-82217-C2-2-P). The term is used without a priori connotations and thus it is understood that the praxeology of scientific culture is the study of the elements and dimensions of this type of culture with respect to praxis, that is, the creation or modulation of behavioural dispositions and actions. It is thus oriented to promote a theoretical understanding, of an interdisciplinary and empirically grounded nature, of the interfaces between the acquisition of scientific information and behaviour, either at the individual level or in community action in experiences of citizen participation or social activism. It includes an analysis of the ways in which the patterns of production, distribution and consumption of scientific knowledge are changing due to the impact of new technologies. It also includes an analysis of the emergent properties that scientific culture manifests when it is expressed as a communitarian attribute. Therefore, the project has been aimed at studying the behavioural dimensions of scientific culture from the point of view of theoretical reflection and empirical analysis, both at the individual level and at the community level.

The search for knowledge along with scientific and technological advances are a fundamental part of what it means to be human. Therefore, the practical dimension of scientific (science) culture actually refers to practically any area of people's lives. For this reason, this book is eclectic both in the topics covered in its chapters and in their approach.

Ana Muñoz van den Eynde's contribution, which opens the book, presents a conceptual model and a bottom-up approach centred on scientific culture, scientific consciousness, and the image of science. The chapter examines the influence of misinformation, false beliefs, and polarization. It also notes that science is being publicly scrutinized for its close relationship to politics and the current political climate. The author concludes that the profound transformations of science, society and the role of science in society are damaging the institution of science.

Santiago Cáceres Gómez, Guillermo Aleixandre Mendizábal and Javier Gómez González review the concept of "engineering culture" and the official postulates, taking into account the social aspects in the acquisition of their related competences. The authors discuss some recommendations to reverse the current situation, based on a systems thinking approach, the inclusion of social and environmental impacts in basic science and engineering courses, and public participation in engineering.

The contribution of José Manuel de Cózar Escalante and Javier Gómez Ferri analyzes the concept of community scientific culture. The authors review the background, make a conceptual clarification and propose a model for its study with several phases. The main idea is that scientific culture can be studied both at the individual and community level. The authors use the wave-particle duality analogy to explain their model through an image.

Carmelo Polino focuses on the relationship between praxeology and social asymmetry. The author raises the idea that scientific culture models have delved little attention to the fact that what we know, value, and do depends to a great extent on our social identity, while the opportunities to practice science are asymmetrically distributed in society. The chapter examines the effects of asymmetry on scientific information consumption and cultural participation. The results show how asymmetry reflects inequality, and the latter weakens democratic scientific-technological culture.

The contribution of Noemí Sanz Merino offers a praxeological analysis of the expert evaluation of benefits implemented in accordance with the European Regulation of Health Claims on food. The chapter shows how epistemic and non-epistemic assumptions determine the operationalization of this case of regulatory science. The author argues that the diversity in the implementation of the health claims regulation demonstrates that the choice of a particular approach is not an inevitable consequence of the available evidence or present uncertainties. It is a consequence of the epistemic culture assumed by experts and of how regulatory objectives are epistemically interpreted.

Montaña Cámara, Virginia Fernández-Ruiz, Laura Domínguez, and Esther Cruz show how 'food neophobia' (distrust or rejection of eating novel or unknown foods) and neophobic behavior could have negative health consequences, since neophobic people tend to consume the same foods repeatedly, so they adopt less varied and balanced diets. An empirical study conducted by the authors indicates that during the COVID-19 pandemic, young Spanish women showed slightly lower levels of food neophobia than before the pandemic. This finding suggests that the pandemic contributed to making these women more aware of what they consume and its relevance to achieving optimal health.

Jesús Rey Rocha, Víctor Ladero and Emilio Muñoz highlight the importance of scientific and technical communication on climate change. The authors show how the research data supports that the evidence of climate change must be accompanied by speeches directed to society, politicians and companies with the aim of leading a common response to achieve the final goal. Reflecting on the situation in Spain, the chapter proposes the relevance of cooperation and altruism, and values such as responsibility, trust, empathy and social justice to more effectively face this threat.

The contribution of María J. Miranda Suárez explores the Amabie challenge in order to analyze the impact that the irruption of non-Western cultures has had on the field of health engagement campaigns, and secondly to explore how historical and popular Japanese stories have an impact on the subjects and their praxis in these COVID-19 times. The alliance of the Japanese Ministry of Health with popular culture was one of the most efficient ways to develop innovative campaigns on antimicrobial resistance. It made it possible to engage the largest possible audiences during the COVID-19 by means of Yōkai Amabie and became a virtual signifier of solidarity.

In the closing chapter, Ana Muñoz van den Eynde describes the image of science in a sample obtained under natural conditions through a marketing campaign on Facebook. Respondents can be characterized as "advocates" of science. They are people very interested in science but from a critical perspective. They believe that science and technology bring benefits, but also risks. A notable finding is that, in their role as 'advocates', they tend to disagree with public participation in decision-making on science and technology issues. They also show a somewhat negative attitude towards science serving politics.

THE IMAGE OF SCIENCE: A BOTTOM-UP APPROACH TO THE ANALYSIS OF THE RELATIONSHIP BETWEEN SCIENCE AND SOCIETY

Ana Muñoz van den Eynde

Since the 1980s, from both the academic and political spheres, it has been considered a priority to identify the most effective mechanisms to manage the relationship between science and society. But there is ample evidence that research on this topic has been hampered by circular thinking and the reproduction of outdated models. To break this vicious circle, this chapter presents a conceptual model about scientific culture, scientific consciousness and the image of science with a bottom-up approach. It also considers the influence of two key elements of the current social context in the way people relate to science. First, misinformation, false beliefs and polarisation. Second, the public scrutiny of science as a result of its close relation to politics and the current political climate. The chapter concludes with the hypothesis that the strong influence of commercialization is fostering a utilitarian image of science. In turn, the utilitarian image reinforces the tendency to base the discourse of science on the "legend" that it is perfect and can solve any problem, a perspective also linked to deference to scientific authority. On the other hand, the uncritical rejection of the utilitarian image and deference to scientific authority together with the loss of cultural authority could help explain the denial of science.

INTRODUCTION

According to the idea of reflexive modernisation or risk society (Beck, 1992), industrial society generates unintended side effects and risks that shake the foundations of social institutions and force society to act. These risks generate new discourses, movements, politics and markets whose evolution cannot be foreseen and thus, the certitudes of industrial society result in the uncertainties of the risk society. In this context, the capacity of scientific expertise to deliver objective knowledge, identify risks, and provide tools to control them is called into question (Boström et al., 2017). Nevertheless, we depend on scientific and technological developments to function in our day-to-day lives (The Royal Society, 1985; Durant et al., 1989). These developments present scenarios that concern the population (Commission of the European Communities, 2000). As a result, the relationship between science and society is not as fluid as would be desirable. It is evident that public concerns grow at the same pace as science's ability to overcome limits that seemed unattainable not so long ago. As Jon D. Miller pointed out, the twentieth century was the century of physics, while the twenty-first century is becoming the century of biology. The advances carried out in the past century avoided direct confrontation with traditional beliefs and values. On the contrary, the advances arising from biology are resulting in disputes more directly related to traditional, religious, and personal values (Miller, 2010).

Identifying the most efficacious mechanisms to manage the relationship between science and society has become a prime line of political and academic interest (Thomas & Durant, 1987, Dierkes & von Grote, 2000; Bensaude Vincent, 2014). Most academic activity has been set under the umbrella of public understanding of science (PUS) studies. Currently, criticisms of the PUS paradigm have led to developing a critical approximation that is increasingly gaining acceptance: the "science in society" or "public engagement in science" paradigm (Bauer et al., 2007). It is rooted in science and technology studies (STS) on public participation but still has not generated an articulated research programme (Cámara et al., 2018).

THE SHORTCOMINGS OF RESEARCH ON THE RELATIONSHIP BETWEEN SCIENCE AND SOCIETY

The origins of this field of research have to be situated in the 1980s and are a result of the "anxious international reactions of institutions, patrons and beneficiaries to emergent public movements that began questioning the radical programs of innovation" developed from the end of the World War II, once people started to realise the consequences they posed for society (Wynne, 2014, p. 61). Until then, technological development had been considered inherently beneficial. From then on, society began to become aware of the potential misuse of technologies, to question the political, social and economic neutrality of technological development, and to feel fear. Therefore, citizens began to demand responsibility. From the perspective of scientific institutions, the need to find mechanisms to recover previous social acceptability emerged, and so began the analysis of society's relationship with science and technology. This analysis has been conditioned by a "deficit model", that is to say, the idea that public concerns about scientific and technological developments are the result of a deficit of knowledge, of trust, or of engagement. Despite the criticisms generated by the assumptions of this model, it has been impossible to eradicate (Wynne, 2014; Bauer, 2016). Its resilience is just the tip of the iceberg of a deeper problem: the fact that research on the relationship between science and society has been hampered by circular thinking and the reproduction of outdated models (Fayard, 1992).

The problem of circularity can be explained by two factors. First, if we consider the distinction between basic and applied science, it can be said that research on society's relationship with science resembles applied science. It has been oriented to obtain useful information for politics and not to know how citizens interact with science. This strategy has generated a kind of flight forward, the tendency to make new proposals without dedicating enough time and effort to reflection. Second, despite the consensus that there is not a unique scientific method, it is widely agreed that scientists share a distinctive methodological culture (Ziman, 1998). But research on science-society's relationship has not been sufficiently embedded in this culture.

In the culture of science, theory is crucial (Ziman, 1998). However, in the field of research on the relationship between science and society, not only has a conceptual framework not been developed but there is also no agreement on the definition, meanings or purposes of the research object. For example, despite scientific culture being an important concept for the PUS paradigm, there is little agreement on its content or how to measure it (Godin & Gingras, 2000).

On the other hand, in the culture of science, instruments are key to obtaining objective data (Ziman, 1998). The development of reliable instruments requires a dialogue between conceptualisation and operationalisation (Hox, 1997). But in this field of research, items and questionnaires have been designed irrespective of any conceptual development about what is being measured and, consequently, how it should be measured (Pardo & Calvo, 2002). On the other hand, the desire to understand the world through analysis is another essential feature of the culture of science (Ziman, 1998). But data from public opinion surveys of science have almost exclusively been analysed descriptively.

Finally, the "public" is supposed to be the main objective of measures designed to reduce the gap between science and society. However, reputable voices in the field have been pointing out for thirty years that we need to increase our scientific knowledge of the public (Lewenstein, 1991; Lévy-Leblond, 1992; Macintyre, 2005; Wynne, 2014; Jasanoff, 2014). There is a tendency in the literature to refer to the "public" as if it were a kind of mass, an aggregate of citizens who share a common perspective on science. More recently, the plural form, publics, has been adopted to indicate diversity and to recognise that generalisations are not only invalid but are often highly misleading (Einsiedel, 2000; Bucchi & Trent, 2014). Anyway, the analyses of surveys of the public perception of science show that there is not a single and shared perception of science, but many (Cámara et al., 2018). There is no homogeneous public that interacts with science, but individuals (persons) that do not fit easily into any generalisation (Toulmin, 2001). It has been found that the variables available in the studies about the public perception of science have limited predictive power (Muñoz et al., 2012). The independent variables make a minor contribution to the variance of the dependent variable and thus generate a large error variance. This is because studies neglect much of the contribution of individual differences to the independent variables that, therefore, becomes part of the error variance (Eysenck, 1997).

THE RELATIONSHIP BETWEEN SCIENCE AND SOCIETY: A CONCEPTUAL MODEL

Scientific (science) culture is an important concept in PUS research. Its promotion responds to the objective of boosting a social voice of quality and, hence, contributing to a constructive dialogue between society and science. Traditionally, it refers to the scientific knowledge, values, interests and attitudes of people regarding science. It also considers how these elements interact and influence decision making in issues involving science, both in daily life and in extraordinary circumstances. Nevertheless, scientific culture is such an ill-defined concept that Godin and Gingras, for example, consider “it is perhaps best to leave the notion of scientific culture to intuition”, although they also point out that “there is general agreement that a broad understanding of the methods of science and a general knowledge of some of its specific content is what is indicated by the notion of scientific culture” (Godin & Gingras, 2000, p. 43). From this perspective, it is assumed that scientific culture is something individuals possess to a greater or lesser extent. On the contrary, Schwartz (2014) considers that culture is external to individuals. This is the starting point from which to propose a conceptual model and bottom-up approach to analyse scientific culture. In this model, scientific culture is not the focus but one of the relevant dimensions of the relationship between science and society to be considered. It is depicted in Figure 1 and adopts a naturalistic approach with insights from cultural psychology, neuroscience and cognitive science.

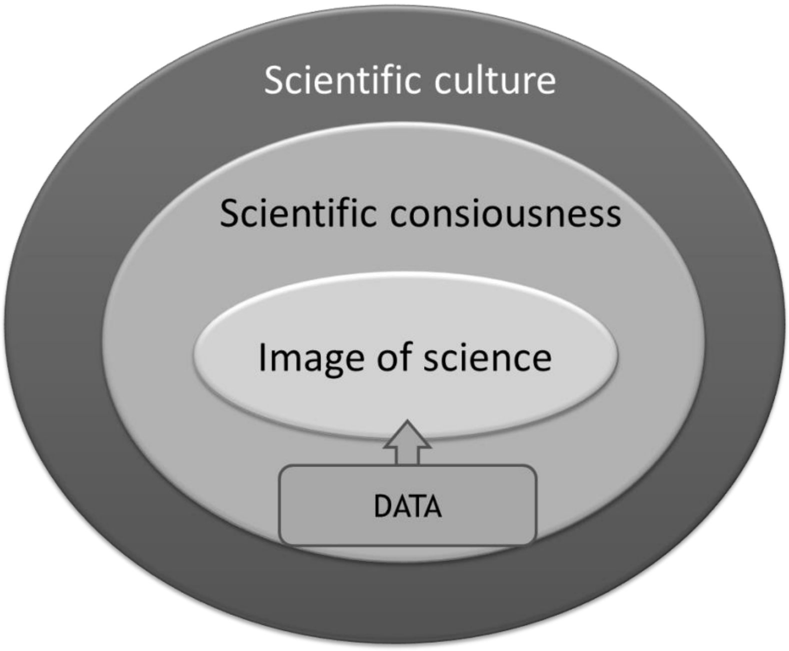

Figure 1. A bottom-up approach to analyse the relationship between science and society

SCIENTIFIC CULTURE

Scientific culture is a dimension of the broader concept of culture. Considering the perspective of cultural psychology, it is assumed that culture provides a clear evolutionary advantage and cannot be understood without a deep understanding of the minds of the people who make it up. People are biological entities, and, therefore, their behaviour has a biological and evolutionary basis. But they are also social and cultural phenomena and, therefore, there is no possibility that they are not linked to forms of behaviour that are structured from the sociocultural environment (Markus & Hamedani, 2007). That is to say, individuals' minds cannot be understood without referring to the sociocultural environment to which they are adapted. In other words, people cannot disconnect from their sociocultural environment (Kitayama & Cohen, 2007).

The notion that culture plays a central role in adaptation and has been key in the development of the human mind has been pointed out by many authors. But I consider the work of three neuroscientists: Antonio Damasio, Gerald J. Edelman and Rita Levy-Montalcini, especially relevant. According to Edelman, culture emerges from the development of language. Once language emerged in the evolutionary process of our species, knowledge, how it is obtained, and the evolutionary process itself became dependent on it (Edelman, 2006). Rita Levi-Montalcini also considers that culture has determined the evolution of our species (Levi-Montalcini, 2000). Antonio Damasio adopts a somewhat different perspective and argues that culture results from the emergence of consciousness in the evolution of mammals and, more specifically, of primates. In this process, the mind was progressively gaining in complexity until the moment that human minds, sustained by higher capacities of memory, reasoning, and language, gave rise to consciousness. Consciousness is a mind endowed with subjectivity and, therefore, it is responsible for knowing and paying attention to the environment, giving rise to history and culture. On the other hand, once developed, culture has added a new mechanism of regulation: sociocultural homeostasis. Basic homeostasis focuses on the process of life regulation. Sociocultural homeostasis is involved in social regulation and, therefore, its products are justice systems, political and economic organisations, arts, medicine, science or technology. Both types of homeostasis are separated by billions of years of evolution but have the same goal, the survival of living organisms. Members of the human species need the interaction of both types of regulation. However, while biological regulation is inherited and, therefore, determined by the genome, cultural regulation is in full and constant development (Damasio, 2010).

As has just been mentioned, humans are biological and cultural beings. From the biological perspective, the brain makes people who they are, and thus it is the product of a code that has been written, rewritten, and edited for millions of years (Damasio, 2010; Sharot, 2017). Culture has a great impact on how people survive and adapt in a given environment (Richerson & Boyd, 2005). It is fundamentally distinct from genetic inheritance at a structural level: while genetic inheritance is primarily vertical and non-strategic for the recipient, cultural inheritance can be vertical, horizontal or oblique. As a result of its structural differences, cultural evolution is more rapid than genetic evolution. In humans, the average time between the birth of parents and the birth of their offspring, genetic G (generation time), ranges from roughly 2 to 3 decades, while cultural G, the average time between learning a piece of information and transmitting it, ranges from seconds to decades (Waring & Wood, 2021). On the other hand, genetic variation is largely random, but cultural variation can be 'guided' by intentional innovation (Boyd & Richerson, 1985). This is something I explore in more detail in the concluding remarks.

Culture includes meanings (concepts) and instruments (tools and institutions) (Markus & Hamedani, 2007). Scientific culture is understood as the dimension of culture that involves socially shared meanings and instruments that have science as its focus. There is evidence that culture is a social feature. For example, it has been found that there are differences in the social perception of science and its applications among Europeans (Bauer et al., 1994; Durant et al., 2000). A strong association between interest in science, being informed about it, and the scientific capacity of the country of reference has also been found. Specifically, evidence shows that the higher the scientific capacity of the country, the more interested and informed citizens are (Muñoz van den Eynde, 2014). On the other hand, there is evidence that citizens' opinions about science and their willingness to engage in science and technology decision-making (an expected result of the PES paradigm) have country related specificities that cannot be explained by the level of scientific and technological development (Muñoz van den Eynde, 2021); instead, they seem to stem from 'the 'integration' or 'embedding' of science in each national culture" (Leach & Fairhead, 2007, p.35).

SCIENTIFIC CONSCIOUSNESS

As in culture, scientific consciousness is a dimension of the broader construct of consciousness. Consciousness is very difficult to define, among other things, due to the traditional tendency to separate body and mind. It is something that both neuroscientists Antonio Damasio and Gerald J. Edelman refer to, albeit in different words. Together with Rita Levi-Montalcini, both consider that the study of consciousness requires seeing it as the result of a biological process; specifically, feedback loops between brain structures and, therefore, as an emergent property of brain functioning. Damasio and Edelman distinguish two types of consciousness. One, present in higher vertebrates, involves having mental knowledge of things in the world and the ability to develop goal-directed behaviours, but only in the present; the other involves being aware of themselves or being aware that they are aware. Although Edelman believes that consciousness is only present in humans, Damasio believes it probably exists in other animals. Levi-Montalcini refers to a single consciousness, exclusive to human beings, which implies having knowledge of their existence and knowing that they are responsible for their actions.

There are also some differences between these authors regarding the function of consciousness. Levi-Montalcini refers to the ability to control our actions, i.e., to responsibility. She defines it as an emergent state of the brain that takes control over the body. Instead, for Damasio, the main contribution of conscience has been to improve our capacity to adapt. As culture is the result of consciousness, Damasio considers economic exchange, religious beliefs, social conventions, ethical rules, laws, the arts, sciences, and technology are cultural instruments that contribute to the survival of the human species. In turn, Edelman considers that the main function of consciousness is laying the biological foundations of knowledge.

Recapping: there are three central ideas on which the three authors agree. First, culture is a distinctive feature of our species. Second, there is an interdependent relationship between culture and human beings to the point that one cannot exist without the other. Third, culture and consciousness are the result of evolution and contribute to our ability to adapt. I consider this translates into the following ideas: 1) the mind is an emergent property of the brain, 2) consciousness is an emergent property of the mind, 3) culture is an emergent property of the consciousness of groups of individuals in interaction, and 4) this emergence occurs as a result of regulation, i.e., of biological and sociocultural homeostasis.

WHAT DOES IT MEAN TO BE "SCIENTIFICALLY CONSCIOUS"?

If we attribute to consciousness what has hitherto been considered culture, to answer this question, we could say that scientific consciousness encompasses not just the understanding of scientific contents but also being aware that science is an essential part of society (Bucchi & Trent, 2014). It also includes learning how to find and assess the quality and accuracy of information (Priest, 2013), when to accept scientific consensus, when to trust experts, and when to assert values that seem contrary to those held by scientists (Jasanoff, 2014).

The product of consciousness are images, i.e., neural maps that contribute to direct our actions (Damasio, 2010) and, hence, scientific consciousness generates an image of science. This image reflects the mental representation of science that individuals conform to when interacting with science in their daily lives in a specific social environment; simultaneously, the social environment influences the citizens' image of science as a result of how society interacts with science. It is assumed that when individuals operate and make decisions in their daily lives, the image they have of science is running in the background (Muñoz van den Eynde et al., 2017).

THE IMAGE OF SCIENCE

There is no homogeneous image of science because there is not "a public", but also because there are different kind of sciences. Traditionally, there were two, academic and industrial (Ziman, 1998). Academic science was aimed at producing reliable public knowledge and functioned through a number of well-established practices that were not formally codified or systematically enforced but may be encompassed by a methodological culture (Ziman, 1998). When the focus is on academic science, it can be said that the feature best describing the science-society relationship is acceptance (e.g., Pardo & Calvo, 1992). In any case, it seems clear that individuals do not "reject point blank the acquisition of new knowledge or the development of technologies that might make their lives longer, easier or more secure" (Jasanoff, 2014, p. 23).

Industrial science, on the other hand, shared the knowledge base with academic science but had a parallel culture in which science is used to produce valuable knowledge to address the issues of daily life (Ziman, 1998). Public reaction to industrial science may be described in terms of people's actual experiences with science and their sense of relevance or irrelevance for satisfying particular needs and interests (Popay & Williams, 1996). From a political perspective, scientific research is justified mainly by its utility (Bauer et al., 2019). This point of view has had its reflection in citizens who have developed a utilitarian view of science: it depends on the consequences (Kerr et al., 1998).

The idea that science is organised on the basis of market principles has led to the emergence of a third "science", an instrumental version that captures material interest and commercial agendas to such an extent that it has become partisan (Ziman, 1998). It is being seen as taking sides, or actually, it is, with the consequent loss of credibility as a neutral arbiter on epistemic matters (Bauer et al., 2019). On the other hand, science is a social institution embedded in the social context of its time, and we are witnessing a global institutional crisis, in the sense of a general and intense conflict about the fundamental assumptions and institutional frameworks (Ansell et al., 2016), that is also putting science in the eye of the storm. When there is deep distrust in industry and government judgments, science as an instrument of policy also generates social distrust (e.g., Ziman, 1998). Therefore, people do not seem to have a negative attitude to science, but some sensitivity about its implications for their worldview (industrial science) or, more important, for their ideology (instrumental science) (Hayhoe & Schwartz, 2018).

In addition to the complexity generated by the social reaction to the different "sciences", the image of science is also complex because it is shaped by multiple factors. The ones that have received more attention to date have been perception (a combination of attitudes and opinions), interest, knowledge and attitudes (Muñoz van den Eynde et al., 2017). Figure 2 shows the depiction of a section of the image of science as a mental map that combines the associations found to date among perception (a combination of attitude and opinion), knowledge, action, interest, trust and engagement.

Figure 2. Representation of a section of the mental map that defines the image of science (Muñoz van den Eynde et al, 2017)

BECAUSE CONTEXT MATTERS

People are extremely susceptible to social influence (Sharot, 2017). From the perspective of cultural psychology, this susceptibility is explained by the bidirectional influence of culture and people's minds. The behaviour of individuals, as biological entities, has a biological and evolutionary foundation. Yet, they are also ineluctably social and cultural, to the extent that people and their social worlds require each other (Markus & Hamedani, 2007).

In their relationship with science, people attribute meaning to scientific facts as a function of a specific social context (Latour, 1993), considering the purpose, impact and social consequences of scientific developments (Engdahl & Lidskog, 2014). As a result, they identify science with the implications of those developments (Macedo, 2019); that is to say, science is not something in itself, independent of its effects.

In the current social context, several factors seem to be having a strong influence on the way people relate to science. In this chapter, I want to highlight two. First, all we know about human cognitive biases suggests that the abundance of information and opinions on the web result in misinformation, false beliefs and polarisation. People can now find information online to support any view or opinion they wish, and that makes them more confident in their opinions and more resistant to change (Sharot & Cook, 2018). Second, science has become such an integral part of modern life and contemporary culture, with widespread and deep implications for individual and social wellbeing (Kandel, 2006), that many personal and policy decisions are to some extent related to it (Durant et al., 1989; Priest, 2013). For that reason, science is closely related to politics and thus subject to public scrutiny and influenced by the political climate of the moment. The denial of scientific facts is not new. What makes the current context especially concerning is that voices are emerging that go far beyond criticising specific scientific facts to denying the very relevance of scientific evidence to inform government decisions (NHB, 2017).

A PARADOX: UNINFORMED IN THE ERA OF INFORMATION

Humans have a strong desire to know. And uncertainty is unpleasant. Therefore, information gaps make people feel uncomfortable while filling them is satisfying. The drive is evolutionarily ancient and is linked to the rewards system of dopaminergic neurons. These neurons send signals from the midbrain, an evolutionarily "old" part of the brain, to many other regions, including the striatum, a part of the brain that processes rewards, as well as areas in the front of the brain that are important for planning. Dopamine is released when we expect a reward and when we receive an unexpected one. The same occurs with information, i.e., information is rewarding. This finding explains the success of the Internet and social media: we are driven to seek information by the same neural principles that drive us to seek water, food, or drugs. There are two explanations for this fact. First, in many cases, information is indeed necessary for survival because advanced knowledge can help us make better decisions. Second, people have learned that information affects their feelings, and they can use information to regulate their emotions. Hence, people selectively try to fill their minds with knowledge that will form pleasing beliefs and avoid information that can cause unpleasant thoughts (Sharot, 2017).

Brain-imaging technologies have also provided evidence that peoples' brain reward centre is strongly activated when propagating information and sharing opinions. In other words, the opportunity to impart our knowledge to others is internally rewarding. The activation of the reward centre drives us to communicate. It is a circuit that has been selected during the evolution of our brains because it ensures that knowledge, experience, and ideas are transmitted, and thus, human societies benefit from the products of many minds (Sharot, 2017).

The human brain is programmed to get a kick out of information, making our current digital era an explosive celebration for human minds. While the agricultural age gave us easier access to nutrition, and the industrial age increased our quality of life, the information era is characterised by its capability to provide stimulation for humans' brains. However, humans are not wired to react dispassionately to information. Data are necessary for uncovering the truth, but they're not enough to change beliefs, and they are practically useless for motivating action. In fact, the great amounts of information people are receiving today can make them even less sensitive to data because they have become accustomed to finding support for absolutely anything they want to believe. On the other hand, accessibility to great amounts of data, analytic tools, and powerful computers is the product of the last few decades, while human brains are the product of millions of decades. The result is people are not driven by facts but by their beliefs. And these are shaped by people's desires, needs and motivations. Therefore, data have only a limited capacity to modify strong beliefs, even when scientific evidence is provided (Sharot, 2017).

Our societies are experiencing a change in the way citizens seek and acquire scientific information. Specifically, we are witnesses to a transition from a warehouse system to a just-in-time system. In the first case, more learned people and institutions are supposed to tell others what they ought to know, and people would store that information in their mental warehouse. But the Internet is radically changing this way of acquiring information. In the just-in-time system, adults seek information when they want it or think they need it. And this implies that salience is the key driver of information seeking (Miller, 2016).

On the other hand, when people are provided with new data, they quickly accept evidence that confirms their preconceived notions (prior beliefs) and assess counterevidence with a critical eye. Because we are often exposed to contradicting information and opinions, this tendency will generate polarisation, which will expand with time as people receive more and more information (Sunstein et al., 2017). Presenting people with information that contradicts their opinion can cause them to come up with altogether new counterarguments that further strengthen their original view, an effect that is known as the "boomerang effect" (Sharot, 2017).

Confirmation bias, i.e., seeking out and interpreting data to strengthen pre-established opinions, is one of the strongest human cognitive biases. When searching for information on the Internet, people are oblivious to the fact that they are often presented with filtered information to suit their prior beliefs: internet search engines provide results that have been individually customised, generating a technology-induced confirmation bias. Therefore, technology is further strengthening the confirmation bias that comes standard with humans. In fact, it has been found that when people discover that they may be wrong, their brains react by generating an "error signal". But when people receive information that does not fit with their prior beliefs or decisions, their brains do not react (Sharot, 2017).

The Internet represents the major source of science-related information for all citizens, including young children (Falk & Dierking, 2010). But not all the available information has the same value or is equally reliable. It has been found that unsubstantiated online rumours, such as the association of vaccines to autism, and mainstream information, such as scientific news and updates, reverberate in a comparable way on the Internet (Del Vicario et al., 2016). Therefore, citizens need to learn how to find and assess the quality and accuracy of the information they find (Priest, 2013), when to accept scientific consensus, when to trust experts, and when to assert values that seem contrary to those held by scientists (Jasanoff, 2014).

The viral spread of baseless or false information is considered one of the most dangerous social trends developed human societies are facing. People are not good at distinguishing the quality of the sources and of the information itself. Besides, social media have made it easy for ideas and arguments, both accurate and false, to spread around the globe almost instantaneously. As a consequence of the confirmation bias, people are prone to appropriate the information that confirms their own thinking and reject the other. Finally, on the Internet, "good" and "bad" information resonates in the same way. All these dynamics suggest that the spread of online misinformation will be very hard to stop (Quatrociocchi, 2018).

The aim of using fake news is to make people think and behave in ways they wouldn't otherwise, e.g., hold a view that is contradicted by overwhelming scientific consensus. They can distort people's beliefs even after being debunked. Repetition makes the information more accessible in people's minds and leads individuals to mistake familiarity for verity. This effect occurs even when citizens know the information presented is false (Hambrick & Marquardt, 2018).

POLITICS, SCIENCE AND THE DISCOURSE ABOUT SCIENCE

The relationship between science and politics is two-way. Policy applied to science (policy for science) refers to decision-making about how to fund or structure the systematic pursuit of knowledge. Science for policy deals with the use of knowledge to facilitate or improve decision-making in general (Brooks, 1964). As the COVID-19 pandemic has shown, science for policy is essential. There have been continuous references to the need to follow experts' recommendations and an emphasis regarding the need to apply scientific criteria to political decision-making.

But as political issues become more scientific, science becomes more political in the sense that the arguments provided when formulating policy are interpreted in a specific political and regulatory context. Hence, the connection between science and politics makes science more exposed to criticism and dependent on public legitimacy (Eden, 1996). Additionally, science is a social institution embedded in the social context of its time, and, therefore, its public legitimacy depends on the legitimacy of other institutions to which it is related. There is no evidence of a declining commitment to the principles of democracy, but there is concerning evidence of a decline in political support that is apparent in three areas: disillusionment with politicians, with political parties, and with political institutions. There are three potential explanations of the decline in public confidence in representative institutions. First, it might be the consequence of the public being better informed about democratic performance. Second, the public's criteria for evaluating politics might have become more demanding and stricter. Third, the performance of representative institutions might have deteriorated (Pharr et al., 2000). Probably, the reason is actually a combination of the three of them. Anyway, it seems that people do not reject the "theoretical" grounds of democracy but its implementation. Something similar occurs regarding science: the pursuit of knowledge in the abstract is highly valued, but discontent with its implementation seems to be increasing steadily.

In this context, in Europe at least, the systematic pursuit for knowledge, which is supposedly the goal of the science policy, has been replaced by the systematic pursuit of economic profit; thus, innovation has become the "gold standard". Consequently, the acronym S&T (science and technology) has been replaced by the acronym R&I (research and innovation). In fact, a search of key terms on the Strategic Plan 2021-2024, document that defines the strategic orientations for the first four years of Horizon Europe, the EU's multiannual framework programme for research and innovation, clearly shows this tendency. It is a 100-page document in which the term innovation and its derivatives appear 308 times (besides the 77 inclusions of the acronym R&I). There are 185 mentions of economy and its derivatives, the word impact appears 175 times, and market is used on 36 occasions. On the contrary, knowledge is mentioned 63 times, in almost all the cases secondarily, as an indicator of impact, not as an objective. Science and its derivatives appear 77 times. Again, from the perspective that they are a result of R&I actions instead of what is being pursued. The acronym S&T does not appear at all. Also, this approximation highlights the instrumental role of science.

Human societies are witnessing the emergence of strong and widespread polarisation. While previously polarisation tended to be seen in issue-based terms mostly related to ideology, a new type of division is emerging, known as affective polarisation, that consists of the deep dislike and distrust of the opposite perspective. It has originated in politics, but it is increasingly influencing attitudes and behaviours well outside the political sphere (Lyengar et al., 2019). In fact, a tendency has been identified, clearly bolstered by the COVID-19 pandemic, to harass and bully scientists providing scientific information on social media about topics, such as vaccines, climate change, the origin of the SARS-2 virus, or the effectiveness of drugs for treating COVID-19 (Nogrady, 2021).

Science denial emerged in the mid-1990s as an instrument of industry to protect its interests. For example, the tobacco or sugar industry started to fund their own research to cast doubt on the certainty of the claims that these products were harmful even when they did not contradict them. The effectiveness of the technique is shown by a 1998 study in JAMA (Journal of the American Medical Association) on reviewing research articles on second-hand smoke, which showed that a “not harmful” conclusion was 88.4 times higher if authors had industry affiliation (Mooney, 2005, p. 10). Increasingly important in the new version of this strategy were think tanks sponsored by industries seeking to block regulation. Research results that opposed or minimised the need for regulation, typically industrially funded, would be labelled “sound science” while pro-regulation research, usually carried on at universities and government laboratories, would be labelled “junk science,” in the interest of manufacturing scientific doubt (Norton Wise, 2006). For example, Bad Science: A Resource Book is a 1993 book including multiple examples of successful strategies for undermining science and a list of experts with scientific credentials available to comment on any issue about which a think tank or corporation needed to spread suspicion (Oreskes & Conway, 2010). Companies and industries have developed a fine strategy of "manufacturing" doubt to protect their products and undermine the need for regulation because debating the science is much easier and more effective than debating the policy. This strategy has been a highly effective public relations tool in the debate over the use of scientific evidence in public policy (Michaels, 2020), i.e., the science for policy.

Worldwide, populist parties are taking advantage of the strategy of manufacturing doubt. These parties are altering the established patterns of party competition and are increasing their representation in the parliaments worldwide (Inglehart & Norris, 2016). Populism is an ill-defined set of ideas around three central elements: anti-establishment, authoritarianism, and nativism (Mudde, 2007), and is characterised by deep cynicism and resentment towards authorities, including intellectual elites and scientific experts (Inglehart & Norris, 2016).

Different theories have been proposed to explain this phenomenon. On the one hand, the perspective of economic insecurity considers that populism is the result of rising socioeconomic inequalities within developed societies. On the other, according to the cultural backlash thesis, populist support reflects a reaction against the process of value change from traditional to post-materialist values that has transformed Western cultures since the late twentieth century. This change has led to a declining emphasis on social class and economic redistribution, growing party polarisation based on cultural issues and social identities, and a more critical perspective towards political institutions and authorities; it has also generated resentment, anger and a sense of loss from which populist leaders and parties are profiting. There is evidence supporting both hypotheses, and probably the two processes reinforce each other. But there is also evidence that the sociodemographic profile of populist supporters is complex and does not adjust sufficiently to the predictions of the economic insecurity or cultural backlash hypotheses (Inglehart & Norris, 2016).

Another possibility is populists are being opportunistic, including what people desire to hear in their messages when facing the threat associated with the uncertainties that characterise Beck's reflexive modernity. Due to the aforementioned disenchantment with democracy, politics is no longer seen as a tool focused on solving problems of coexistence and is seen as a social problem (Muñoz van den Eynde, 2019). Political theory stems from the hypothesis that citizens decide their vote based on their opinions and their needs (Birkland, 2005). Opinions have been linked to ideological positioning, which is still used as an explanatory variable for electoral results, although this is losing explicative power. On the contrary, the vote seems to be increasingly determined by people's needs, which are closely linked to their emotions (Damasio, 2010). Therefore, populist parties and leaders would be taking advantage of issues surrounded by societal debate, such as the restrictions imposed by governments to deal with the COVID-19 pandemic, the denial of climate change, or anti-vaccine activism, as fishing grounds for votes. There would not be an ideological or economic inequality background, but the opportunistic attempt to seduce everyone that is having difficulties dealing with the current state of affairs.

Despite it is not new, science denialism is spreading nowadays and raising all the alarms. For example, in 2019, the World Health Organization identified mistrust of vaccines as one of its priorities, stating that rumours and misinformation about them, mainly spread on the Internet, was a bigger threat than the diseases themselves (Tavani et al., 2021). In parallel with the COVID pandemic, an infodemic was generated; the rapid and far-reaching spread of informational noise and even misleading or false information with potentially dangerous impacts on society’s capacity to respond adaptively (Galotti et al., 2020). These are just examples of a broader phenomenon: public opinion is questioning science that, in turn, is being accused of hiding the truth and being influenced by lobbies, an evident side-effect of the strategy of manufacturing doubt. This takes place in a context in which there is growing adherence to conspiracy beliefs and fake news, and there is a positive and quite strong correlation between adherence to conspiracy beliefs and science denial (Tavani et al., 2021). The instrumental mode has gained such a foothold that it determines the very conception of science today (Ziman, 1998). And the consequence is the social reaction to science is becoming ideological and polarised. Science seems to be either all good or all bad, and both ideas of science are wrong and dangerous (Collins & Pinch, 1993).

Therefore, it can be said that the discourse about science is being built around the confrontation of two poles. The “positive” one is defined by the belief in the legend of science, the stereotype of idealised science in all its aspects (Norton Wise, 2000; Ziman, 1998) to the point that speaking of non-scientific knowledge is considered a contradiction in terms, as if there were no other reality than that of the world revealed by science (Ziman, 1998). The belief in the legend of science is associated with the unrealistic expectation that there would not be a problem humankind will have to face that could not be solved by science (Nelkin, 1990; Thomas & Durant, 1987). The “negative” pole is characterised by the rejection of the legend of science fostering the rise of “anti-science” movements (e.g., against climate change or vaccines) (Collins & Pinch, 1993). The rejection of science as an institution is valued by these citizens, something of which certain sectors of politics linked to anti-intellectualism and populist positions are taking advantage. Anti-intellectualism is the generalised mistrust of intellectuals and experts (Merkley, 2020). Another two components can also be identified: (1) anti-rationalism, or the dismissal of critical thinking as a desirable trait; and (2) thoughtless instrumentalism, or the devaluing of long-term payoffs for short-term material gain (Rigney, 1991). Anti-intellectualism is strongly associated with opposition to scientific claims on relevant societal issues, such as climate change, nuclear power, GMOs, or vaccination. This association is stronger for respondents highly interested in politics. And higher levels of anti-intellectualism increase people’s opposition to scientific claims. On the other hand, anti-intellectualism breeds populism, a worldview that explains political conflict by means of a confrontation between ordinary citizens and a privileged social elite (Merkley, 2020) that has become a powerful mechanism of political mobilisation (Oliver & Rahn, 2016).

As it has formerly been stated, despite the criticisms, the “deficit model” has shown great resilience and remains fully in force (Wynne, 2014; Bauer, 2016). In the same way, it has been found that the “legend of science” negatively correlates with science knowledge and the scientific productivity of countries (Bauer, 2008), and it is widely accepted that building a satisfactory relationship between science and society requires rejecting the legend of science. However, there are still scientists who refuse to accept the idea that science cannot provide absolute "truths" nor a universally applicable answer to every problem (Ziman, 1998). Simultaneously, science is constantly being called upon by citizens, governments, and other social actors to make accurate predictions, for example, of the impact of human activities on the environment (Steel et al., 2004). Therefore, the utilitarian image of science generated by its instrumental version also has an impact on the discourse about science. Utilitarianism favours the legend of science. Its criticism favours science denial.

EPILOGUE

Figure 3 graphically recaps what has been said so far in this chapter. It seems that science is being excessively directed by a commercialising aim that is promoting the predominance of its instrumental version. In turn, this predominance tends to foster a utilitarian image of science that, in turn, strengthens the tendency to make the discourse about science grounded on the "legendary" perspective. That is also promoted by deference to scientific authority. On the other hand, the uncritical rejection of the utilitarian perspective and deference to scientific authority, combined with the loss of science's cultural authority, could explain science denial. As mentioned, the actions of these forces take place in a context influenced by the Internet and misinformation, politics, polarisation or how humans are as a result of cultural and biological evolution.

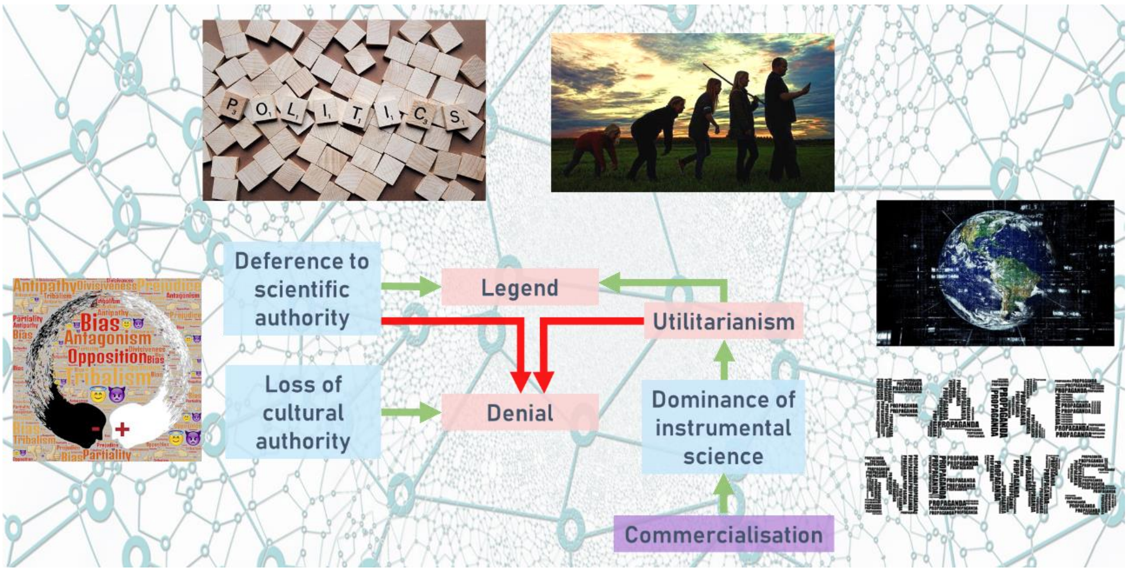

Figure 3. A hypothesis about the social context of science[1]

Deference to scientific authority is the belief that decision-making about science and technology should be addressed only by the scientific community, without the participation of other social actors, i.e., it refers to views of who should be involved in decision-making in issues with societal impact (Howell et al., 2020). In modern society, authority is based on reputation and consent, and thus needs to have legitimacy. Considering this, cultural authority refers to the aspiration to be a reputable institution able to speak truth to power (Bauer et al., 2019). If it is assumed that the cultural authority of science means believing that science is a truth-maker, then deference to scientific authority stems from cultural authority (Howell et al., 2020). Nevertheless, the cultural authority of science can also be considered an authoritative way of understanding the world by providing reliable and objective knowledge (Ziman, 1998). From this perspective, cultural authority is not necessarily the origin of deference to authority.

Misinformation is an intentional cultural innovation that is taking advantage of human nature, a result of a long trajectory of biological evolution. To deal effectively with misinformation and its dangerous consequences, we should first dismantle the myth that people's cognitive processing is rational by default (Kahneman, 1994). The rational agent model stems from two premises: (a) people make decisions rationally, analysing in detail and weighing all the pros and cons, and (b) emotions explain most of the situations in which people stray from rationality (Kahneman, 2011). But evidence has repeatedly shown that people's behaviour does not match those premises (Simon, 1978). In fact, it has been found that humans' basic tendency is to default to processing mechanisms of low computational expense (Stanovich, 2020). As a consequence, knowledge alone does not provide citizens with a vaccine against the social virus of fake news (Campbell & Friesen, 2018) and

1 Free images from Pixabay by Gerd Altmann, Gordon Johnson, Pete Linforth, jplenio, Wokandpix and John Hain.

science denial. It can even be counterproductive (Kahan, 2012). To facilitate "immunity" against the "disease" of bias, it is useful to encourage people to accept ambiguity, engage in critical thinking and reject strict ideology (Campbell & Friesen, 2018).

Critical thinking may be understood both as a collection of cognitive skills that allow us to think reasonably in a goal-orientated fashion, and the disposition to use those skills when necessary; anyone can improve these skills with training, and the benefits have been shown to persist over time (Butler, 2018). Therefore, in developing scientific consciousness and being “knowledge-able” (Jasanoff, 2011), people need a “*mindware*”, i.e., “whatever knowledge, understanding and attitudes you have that support you in making the best use of your mind” (Perkins, 1995, p. 13). In this chapter, we have assumed that making the best use of the mind implies acting reasonably instead of rationally. Acting reasonably involves using intellectual or practical skills to deal with human situations, trying to adapt to the circumstances and the specific situation. Acting rationally means focusing only on the content of general theoretical abstractions while ignoring the situation in which they are presented. Reasonableness is grounded on the fact that everyday experience is also influenced by “where and when”; in contrast, rationality stems from the assumption that general theoretical abstractions can be applied always and everywhere (Toulmin, 2001). It is also assumed that the *mindware* that allows citizens to think critically is a feature of scientific consciousness, i.e., an attribute of individuals that also depends on scientific culture considered as a social attribute.

It has been mentioned above that humans are the result of both cultural and biological evolution. It can be said that science denial or the promotion of fake news are becoming intentional cultural innovations contributing to cultural G becoming instantaneous, while current social dynamics are increasing genetic G (Waring & Wood, 2021). Along millions of years, emotions have been extremely relevant drivers of human evolution. Because sharing ideas usually takes time and cognitive effort. On the contrary, sharing feelings happens instantly and easily; thus, emotions are highly contagious. The mechanism involves brain synchronisation. By synchronising people’s brains, emotions automatically allocate their attention in the same direction and generate a similar psychological state; in turn, this prompts people to act and view the world in a similar way. Emotion equates the physiological state of people, making it more likely that they will process the information in a similar manner. The brains of humans have evolved to transmit emotions quickly to one another because emotions often convey important information about our environment (Sharot, 2017). Emotions not only allow us to make "smart" decisions without having to think “smartly”, but they are essential to our survival (Damasio, 2010). Therefore, it does not seem sensible to consider that scientific consciousness should involve avoiding emotions -thinking with their gut, in the words of Carl Sagan (1995). On the contrary, it would be much more useful and realistic to consider that to promote scientific consciousness, we should generate negative emotional (from the gut) reactions in people when facing unsupported information, attempts at emotional manipulation, lack of evidence, or science denial.

On the other hand, people’s beliefs about their capabilities to exercise control over their own level of functioning and over events that affect their lives (self-efficacy beliefs) are central to determining their willingness to act and their behaviour (Bandura, 1993). It has been found that knowledge plays a central role in defining the image of science, and that self-perceived efficacy regarding science is more relevant than knowledge of scientific facts (Muñoz van den Eynde, 2021). There is also evidence that knowledge of the processes and practices of science increases the acceptance of specific scientific claims, counteracting the influence of social identity factors (Weisberg et al., 2021). Social identity is essential to explain polarisation. It is people's sense of who they are based on the group(s) to which they belong (McLeod, 2008). The groups people belong to are an important source of self-esteem; thus, to increase their self-image, people will enhance the status of the group they belong to (in-group) and will seek to find negative aspects and worsen the status of the out-group (the others) (Tajfel & Turner, 2001). That is to say, people divide the world into "them" and "us" based on a process of social categorisation (McLeod, 2008). Therefore, to address the dysfunctionalities in the relationship between science and society, it would be convenient to improve the perceived self-efficacy of citizens regarding S&T. It seems that improving people's knowledge of how science works would be a good strategy (Weisberg et al., 2021).

Science denial does not actually imply a global rejection of science but is mainly motivated by economic or ideological reasons (Macedo, 2019), and thus becomes a belief. Although initially, this might seem like an advantage, it is actually its main problem because these motivations cannot be dismantled with facts. Evidence has been found that, on the one hand, people are extremely susceptible to social influence. But in the face of prior decisions and beliefs, social influence may fail. On the other hand, information is evaluated relative to pre-established (prior) beliefs. The further away new data is from a person's prior beliefs, the less likely it is to be considered valid. Finally, the greater people's cognitive capacity, the greater their ability to rationalise, interpret information at will, and to twist data creatively to fit their opinions. These mechanisms explain the inefficacy of offering facts and figures to change people's beliefs (Sharot, 2017).

The human brain has evolved to control the body so that it can manipulate the environment. This explains why the intense desire for control makes it difficult for people to give up even when they should. Our biology is set up so that we are internally rewarded with a feeling of satisfaction when we are in control, and internally punished with anxiety when we are not. In general, controlling our environments helps us thrive and survive. But altering people's beliefs is a way of exerting control over them (Sharot, 2017). Also, research on a phenomenon called the backfire effect shows that when people are presented with facts that cause them to feel bad about their identity and worldview, they refuse to accept the facts (Tsipursky, 2018). On the other hand, during periods of confusion, lack of governmental direction, economic chaos and information overload, the need for certainty is accentuated, also generating a retreat into absolute ideologies and promoting polarisation (Hayhoe & Schwartz, 2018). The worry that we are becoming a "Post-Truth Society" where fake news rules the information diet of the average member of the public signals concern over the loss of authority over basic facts (Bauer et al., 2019). This is the context we are facing.

Finally, science is facing an institutional crisis that stems from profound transformations of science, society, and science's role in society (Saltelly & Funtowitz, 2017). As previously mentioned, science has made a transition from "academic" to "industrialised" and "instrumentalised". Academic science represents a social order that relies on established relationships of personal and institutional trust as a result of sharing norms, values and practices. But in the transition from academic to industrialised, science has developed practices, such as privatisation, orientation towards industrial, economic and social application, bureaucracy, etc., that have crystalised into the instrumental mode. And this mode has become dominant both in the use of resources and in the direct impact on society (Ziman, 1998). Collins and Evans (2017) consider that the values of science are not only good and necessary for the institution but might be of help in facing the institutional crisis of democracy. They consider that scientific facts and results are continually disputed and hence are not central to our culture. On the contrary, scientific values are not disputed and, therefore, might be key to facing the loss of values that is negatively affecting developed societies as a result of the dominant role they have assigned to the economy and the market.

Objectivity is what makes science so valuable for society (Ziman, 1998). But the aforementioned transformations of science have led to a wide range of questionable research practices (Martinson et al., 2005; Szomszor & Quaderi, 2020) that collide with the pursuit of objectivity. They are also linked to the shift in the reward system of scientists: from one in which trust and value are inferred as the commitment of the experts to the unspoken norms of science (Ziman, 1998) to another in which the value of experts is identified from objective metrics based on the publication of research results (Saltelly & Funtowitz, 2017). Consequently, the system of governance and quality control of science through the peer-review process has artificially turned into a resource of predetermined scarcity for which scholars have to compete (Bon et al., 2017; Martinson et al., 2006). The decision to adopt the norms of the culture of academic science is taken individually, and these norms are hard to live up to (Ziman, 1998). Self-regulation is possible when individuals share a culture that promotes objectivity, trust and cooperation but becomes a utopia in a competitive context dominated by an instrumentalised version of science.

Objectivity conflicts with the desire to obtain social attention and impact, and when it is lacking, self-correction cannot be expected. There are obvious signs that the current context of science does not encourage objectivity and self-regulation (Martinson et al., 2005, 2006; Saltelli & Funtowitz, 2017). “Without a trusted record of research, it is impossible to reliably build on previous ideas, replicate results, or effectively utilize the outcomes of research” (Szomszor & Quaderi, 2020). This future scenario can become our present if we do not develop measures to promote scientific rigour over spurious considerations. Scientists need to reject the discourse of the “legend of science” and avoid dismissing valuable forms of evidence because they do not fit their methodological pre-commitments. But they also should avoid succumbing to the temptation of retreating to value neutrality. Human beings have values, also scientists. And their values influence their work (Oreskes, 2019). But in the task of preserving the values of the culture of science, scientists need the support of the other elements of society: if we all, as a society, fail in this task, “a crucial element of the culture that sustains democratic societies will be lost” (Collins & Evans, 2017, p. viii).

THE ENGINEERING CULTURE: THE NEED FOR IMPROVED EDUCATION ON SOCIAL RESPONSIBILITY IN ENGINEERING STUDIES

Santiago Cáceres Gómez; Guillermo Aleixandre Mendizába; Javier Gómez González

Criteria for accrediting engineering programmes in different countries identify the ability to analyse the effects of engineering solutions in social and environmental contexts as one of the skills to be acquired during the academic training period. However, the assessment of this kind of competence among university graduates is far from achieving the stated objective. In fact, several longitudinal studies have shown that a common situation is the opposite. Engineering graduates have less consideration of the relevance of social and ethical aspects of their professional activities than when they started their studies. Current engineering education, which involves the transmission of cultural elements that make up the "engineering culture", leads some students to the conviction that only scientific or technological skills and competences are necessary for their right professional performance. Bearing in mind this situation, it is convenient to revisit the concept of "engineering culture" and the official postulates on the consideration of social aspects in the acquisition of their related competences. Some recommendations are discussed in order to revert the current situation: a system thinking approach, inclusion of social and environmental impacts in core science and engineering courses, and public participation in engineering.

INTRODUCTION

Criteria for accrediting engineering programmes in different countries identify the ability to analyse the effects of engineering solutions on social and environmental contexts as one of the skills to be acquired during academic training. However, the assessment of this kind of ability among university graduates is far from achieving the stated objective for several reasons. On one hand it is considered to be a soft skill that does not belong with the core competences of the professional practice of engineers; on the other hand, they are not sufficiently integrated with the scientific or technological channels of formal education.

In fact, several longitudinal studies have shown that the situation tends to be the opposite. Engineering graduates have less consideration for the relevance of social and ethical aspects of their professional activities than they did when they started their studies. In some cases, therefore, current engineering education which involves the transmission of cultural elements making up the "engineering culture" leads some students to the conviction that they need only scientific or technological skills and competences in order to perform satisfactorily as professionals. This scenario arises despite the widespread awareness of the undesirable social and environmental impacts of technology on various stakeholders (workers, users and citizens in general).

Bearing in mind this situation, it is considered pertinent to review the concept of “engineering culture” and the official postulates on the consideration of social aspects in the acquisition of their related competences. In this chapter the main results of international literature on graduates' perception of the relevance of including social aspects in professional practice are explored. Based on the above analysis, some recommendations are discussed in order to reverse the current situation:

- Adopting a systemic approach to engineering education so as to move away from restrictive assumptions which give a linear reductionist view of problems.

- Including the social and environmental impact of engineering activities in core science and engineering courses, including design processes and project management.

- Incorporating public participation tools in the process of the definition of technical problems and in the generation of possible solutions as an inherent element of any social and environmental assessment.

ON THE CONCEPT OF CULTURE AND PROFESSIONAL CULTURE

Human groups develop cultures which are subject to research in cultural anthropology, sociology, and other social sciences. These sciences are based on the belief that culture is present in any kind of human grouping, e.g., by nations, ethnicity, age, or profession. These cultural frameworks shape the way of life of individuals belonging to these different groups. Despite this consensus, research is hindered by the ambiguity and the plurality of the meanings of the concept of culture, as it is shown by the 164 definitions of the concept given by Kroeber and Kluckhohn (1952). This figure has even increased since then (Bauman, 1973).

The concept of culture predates the 19th century and is present in the Middle Ages to refer to the set of elements which cultivate and improve human beings. However, as a scientific concept it was born with Tylor (1871), who grouped together in a "complex whole" the social, tangible and intangible dimensions which establish the differences between peoples. From its origin, the scientific use of the term progressively lost its globalising character and eroded its tangible basis, shifting its focus to what Stocking (1963) refers to as internal or ideational realities. Nowadays in most cases the core of the concept of culture is the intangible meanings shared by a group. From the point of view of organisational sociology, culture includes mainly the “soft” elements present in the life of the group (Schein, 1985). These intangibles include values, attitudes, meanings, and the knowledge possessed by a social group, including scientific knowledge. This latter addition is controversial. As Lamo de Espinosa (1996) declares, there is an opposition between science and culture; he points out that science is universally valid knowledge while culture reflects the values and constructions of meaning of a group with local validity and focus.

Professional groups working in different scientific disciplines develop cultures in the same way as any other group. In fact, each scientific discipline is articulated from a coherent set of practices, cohesively bound together by axioms or methodological principles. Moreover, each scientific discipline also has shared beliefs which may be subject to anthropological study as in any other group. In the 1930s Fleck (1979) develops the idea that is possible to identify styles of thinking which unite scientific communities. In a similar way Merton (1973) points out that values, rather than unity of thought, are the aspect which explains the cohesion of the scientific institution. With an anthropological approach, Geertz in 1976 is able to study disciplines as cultural systems, starting from a dense ethnographic description which allows him to develop a line of research very similar to the fieldwork carried out by laboratory ethnography (Latour & Woolgar, 1995; Traweek, 1988).[2] In a complementary manner, Karin Knorr-Cetina (1999) identifies and defines the concept of epistemic culture as a set of agreements and mechanisms united through affinity, necessity, and historical coincidence which in a given scientific field allows the members of the group to be sure that they really know what we know. Therefore, an epistemic culture is a culture which allows the creation of knowledge and its validity within a group; it mainly consists of processes and expert systems which guide the activities of scientists. A central idea behind Knorr-Cetina's studies is that different scientific fields have different epistemic cultures.

Understanding the culture of a specific group has important practical applications. For example, a social player wishing to intervene in the behaviour of a group has among other alternatives the possibility of altering the cultural framework of that group. In this sense, modifying a culture may be quite an effective strategy to affect the behaviour of groups but this is difficult to achieve. There is consensus on the structural character of a culture, and it is clear that culture influences the behaviour and the social action of individuals, although the ways in which culture affects individuals is open to debate.

The objective of this chapter is to analyse the culture of a specific group, engineers, as a prerequisite for transforming it and to reflect on the role of university education in the establishing of this culture. The publication *The Two Cultures and the Scientific Revolution* by Snow (1959) served as a catalyst for the debate on scientific culture and the need for increasing the basic training of future researchers. This study generated a strong debate and reaction in scientific institutions and created awareness of the need for including humanities in engineering education.[3] At that time the objective of improving the educational training of scientific and technical personnel in social and scientific topics became generalised (Iranzo Amatriain & Blanco Merlo, 1999). Subsequently the OECD (1972)[4] issued an interdisciplinary document which insisted on the need for increasing the training base of technologists (Williams et al., 2018).

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2 Unpublished speech titled "Toward an Ethnography of the Disciplines" presented in 1976, held in Folder 9, Box 222 of the Geertz papers held at the Special Collections Research Center of the University of Chicago Library.

3 This movement is linked with the creation of the Science Studies Unit in 1964 at the University of Edinburgh, which is the home of the Strong Programme in the sociology of knowledge.

4 The OECD (Organization for Economic Co-operation and Development) is an intergovernmental organization of high-income countries which operates as a think-tank to resolve common problems, identify good practices, and coordinate the domestic and international policies of its members.

This succession of studies and ideas has stimulated the study of engineering culture which has become a relevant research programme owing to its practical implications. Within the research on engineering culture a major area of analysis is related to technological culture, which often focuses on cultural development. Furthermore, empirical approaches also exist which attempt to describe the general parameters of engineering culture in different contexts. Within the latter it is possible to identify at least two lines of research. On one hand, studies on engineering culture and gender represent a response to the fact that both the engineering profession and academia are highly masculinised (Bastalich et al., 2007; Robinson & McIlwee, 1991; Schmitt, 2021). On the other hand, studies on ethical attitudes (Guntzburger et al., 2017; Hauser-Kastenberg et al., 2003) have given rise to specific publications such as Science and Engineering Ethics.

THE CULTURE OF ENGINEERING

There is no consensus or clear theory regarding engineering culture. This culture is not even monolithic as variations occur in the practice of engineering due to the differences in cultural contexts between countries. However, it is possible to identify a common basis which defines the education and practice of the profession of engineering and can help us to understand engineering culture. This common foundation is strengthened by the recognition of professional engineering programmes by countries in international agreements on the definition of engineering education.

There are several bodies which contribute to the definition of what constitutes engineering; which qualities a person must acquire in order to practise the profession; or which attributions society confers on the profession. These include professional associations (which also define the ethical codes of the profession), companies, governments, educational institutions, and society in general.

Within the study of engineering culture, a relevant field of analysis is that of the characterisation of the culture of engineering by higher education institutions, at which students acquire a series of professional competences which supposedly prepare them for their future professional practice. These competences comprise knowledge, skills and attitudes. This relevance is justified by the need for identifying areas of activity and competences of future professionals in the early stages of their lifelong learning process.

One of the common bases which characterise the engineering culture is the significant role of social aspects in the practice of engineers due to the increasing demand for society and professional bodies to combine their practice with the addressing of social and environmental needs. Among these demands is the greater concern as to the negative social impact of the electronic industry throughout its lifecycle[5] and digital technologies in general.[6]

5 For example, the exploitation and trade of minerals in conflict zones (Public Law 111-203-July 21, 2010. Dodd-Frank Wall Street Reform and Consumer Protection Act); the health problems of workers (Kim et al., 2014; Bailar et al., 2002; Lécuyer, 2017) and also the health problems of communities surrounding manufacturing plants (Pellow & Park, 2002; Smith & Woodward, 1992); poor working conditions and low wages in some territories (CEREAL, 2007; Lüthje, 2002); the generation of large amounts of toxic waste (Hopson & Puckett, 2016; Huo et al., 2007; Puckett et al., 2002; Yang et al., 2013).

6 For example, the reduction of privacy and increase of control on the Internet (Mistreanu, 2018); the political interferences created on social networks (Cadwalladr, 2019).

This role is bidirectional as society influences the education and practice of engineers and at the same time engineering practice influences the culture of a society. The changes over time in the definition and implementation of the engineering syllabus constitute an example of this interaction.

THE CULTURE OF ENGINEERING AND HIGHER EDUCATION ACCREDITATION AGENCIES

In the characterisation of the culture of engineering shaped by higher education institutions, the *Washington Accord* drawn up by the International Engineering Alliance (2014) is a key reference.[7] Moreover, the tracked experience in a New Zealand University gives some interesting insights. The Accord sets out the generic requirements of higher education studies in engineering to ensure mutual recognition among the signatory countries. In some countries these requirements are used to define national standards.

The education of engineers begins with a university degree which may be recognised by the Accord, continues through work experience to develop the necessary professional competences and personal maturity, and is extended throughout their working lives by updating skills, which are measured and assessed against a set of standards defined in the Accord.

The Accord defines twelve aspects corresponding to the competences of an engineering graduate[8]. All of them are common to all engineering programmes. They can be grouped into five categories: mathematics and natural sciences, engineering, design, management, and arts and humanities. The *Washington Accord* stresses that a professional engineer must have “the ability to work on complex problems with a high degree of uncertainty”.

These elements provide a generic definition of the main formal components of the culture of engineering in the field of education, although differences may occur between universities or countries. According to Mosterín (1993)[9] and Schein (2004), who distinguished three dimensions in the concept of culture, it is possible to group these elements into representational, axiological and practical dimensions (Table 1).[10]

Using an empirical approach, Godfrey & Parker (2010) conducted semi-structured interviews of students and lecturers at a university in New Zealand to explore the main characteristics of the

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7 The Washington Accord is an international accreditation agreement for professional engineering academic degrees. The signatory for each jurisdiction is the recognized organization for accreditation of professional engineering qualifications. It was established in 1989 by the founder members of Australia, Canada, Ireland, New Zealand, the United Kingdom, and the United States. Today there are 21 signatory countries.

8 The twelve aspects are: engineering knowledge, problem analysis, the designing/development of solutions, research, using modern tools, the engineer and society, sustainability and the environment, ethics, individual and teamwork, communication, project management and finance, and lifelong learning.

9 As quoted in Quintanilla, 2005.

10 The representational dimension is constituted by knowledge, beliefs, assumptions, conceptual or symbolic representations, and meanings concerning engineering and technology. The axiological dimension includes values and norms of behaviour linked to engineering and its practice and also to technology. The practical dimension refers to behaviours, skills, operational knowledge, and also artefacts including engineering organisations. The latter is the most visible of the dimensions of engineering culture.

culture of education in engineering. They distinguished six dimensions in that particular case, three of which are especially interesting as they are in line with the generic cultural elements of the Washington Accord previously mentioned.[11]

REPRESENTATIONAL	ENGINEERING KNOWLEDGE
Axiological	The engineer and society
Axiological	Sustainability and the environment
Axiological	Ethics
Practical	Problem analysis The designing / development of solutions
Practical	Research Communication
Practical	Using modern tools Project management and finance
Practical	Individual and teamwork Lifelong learning

Table 1. Classification of aspects of the Washington Accord by Mosterín and Schein: dimensions of technology (Source: Own work)

Firstly, Godfrey & Parker emphasise that the engineering "way of thinking" is characterised by different patterns. It focuses on things that work, their usefulness, and their functionality. Engineers' work is oriented towards a tangible, definable, measurable, and quantifiable reality. According to this approach, abstract or philosophical concepts linked to ethics and sustainability are acceptable as long as they are considered within a context which is both relevant and pragmatic.

Mathematics plays a relevant role both as a tool and as one of the languages of engineering practice (drawing is the other). In addition, the understanding of reality is linked to the well-defined actions of calculating, determining, explaining, predicting, and sketching and drawing so that accurate values can be obtained.

Knowledge and mathematical and scientific procedures are free of gender and racial connotations, which strengthens the idea of neutrality in engineering practice. From a cultural point of view gender and racially appropriate solutions are considered as limits to the design or development of the component, equipment, system, or service. The possibility of different epistemologies is not part of the debate.

There is a prevalence of visual communication. The use of diagrams and graphical elements is another essential tool for structuring and communicating knowledge. In contrast, the written and spoken language is more frequent for logical guidelines and commands, avoiding opinions, arguments, or ideological reflection.

11 The dimensions of Godfrey & Parker (2010) are as follows: the way of thinking, the way of doing, the meaning of being an engineer, the acceptance of difference, relationships, and relationships with the environment.

Problem solving and designing are two central activities in an engineer's way of thinking. Problem solving is dominated by a reductionist top-down approach in which complex problems are broken down into simpler ones. During their education engineers are taught to work within constraints and by agreement. They must produce realistic solutions which are both cost-effective and time-effective.

When designing, the notion of "the best solution" considering all constraints rather than perfect solutions is brought up. On a regular basis engineer neither define needs nor problems nor decide what the valid solution should be but rather advise their clients on possible alternatives or significant problems as to the client's initial ideas about the work to be done.

Secondly, in “the way of doing” of engineers, Godfrey & Parker remark that the acquisition of competences during their education is demanding in terms of time and intellectual effort but confers a social status to engineering.

In their practice engineers solve problems under two assumptions: there is a solution to every problem and with the appropriate expert knowledge and a toolbox of skills and procedures it is possible to solve any problem. Time restrictions are of special importance in their practice. Deadlines, planning, and the assignment of tasks are always present in their daily practice.

Although lecturers share the belief that competences on communication and professional development, management, and social and environmental responsibility are necessary in line with the accredited degrees, in their everyday practice they tend to marginalise them in comparison with scientific or technological competences.

Thirdly and finally, Godfrey & Parker point out that “the meaning of being an engineer” is characterised by having an above-average achievement of competences in scientific and mathematical understanding. Rather than being idealistic, engineers are pragmatic, proactive, and capable of performing tasks both efficiently and effectively; in addition, they are socially valued for their efforts to do useful things based on a difficult task.

THE INCLUSION OF SOCIAL FEATURES IN ENGINEERING CULTURE IN HIGHER EDUCATION

Due to the embeddedness of the practice of engineers in society, it would be interesting to know to what extent social features are integrated in the culture of engineering in higher education, and furthermore, to what extent these social features help future engineers to acquire a sense of responsibility towards the welfare of society.

The *Washington Accord* hints at the answer to the first question, as it explicitly includes social features in the characterisation of graduate attributes and their professional competencies. Some of the elements of the graduate attribute profile of *Washington Accord* take into consideration the relationship between engineering and society, for the most part those which were previously grouped in the axiological approach (International Engineering Alliance, 2014, pp. 14, 15):

“Design solutions for complex engineering problems and design systems, components, or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations” (WA3).

“Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems” (WA6).

“Understand and evaluate the sustainability and impact of professional engineering work on the solution of complex engineering problems in societal and environmental contexts” (WA7).

“Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice” (WA8).

Similarly, an element of the knowledge profile of the engineer of the *Accord* takes into consideration this relationship (International Engineering Alliance, 2014, p. 9):

“Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; and the impacts of engineering activity – economic, social, cultural, environmental and sustainability” (WK7).

Furthermore, the *Accord* also defines some professional competencies including social features of the profession (International Engineering Alliance, 2014, pp. 12, 13):

“Recognise the reasonably foreseeable social, cultural and environmental effects of complex activities generally and have regard to the need for sustainability; recognise that the protection of society is the highest priority” (EC6).

“Meet all legal and regulatory requirements and protect public health and safety in the course of his or her activities” (EC7).

“Conduct his or her activities ethically” (EC8).

This integration of social features in culture in engineering in higher education can be further corroborated in the accreditation documents of engineering studies of different countries (Table 2).

COUNTRY	[ELEMENT OF] COMPETENCY	REFERENCE
Canada	**Impact of engineering on society and the environment:** An ability to analyse the societal and environmental aspects of engineering activities. Such ability includes an understanding of the interactions of engineering with the economic, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions, and the concepts of sustainable design and development and environmental stewardship	(Engineers Canada, 2017, p. 14)
Ireland	**[Chartered Engineers]** PO5. Professional and Ethical Responsibilities. (i) Understanding and appreciating the environmental, social, and economic impacts of their judgements and promoting the principles and practices of sustainable development	(Engineers Ireland, 2021, p. 13)
Japan	**Criterion 1 Learning Outcomes** (2) The ability to understand its effect and impact on society and the nature of professional activities and to understand professionals' social contributions and responsibilities*	(JABEE, 2019, p. 10)
United States	**Criterion 3. Student Outcomes** 4. The ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions within global, economic, environmental, and societal contexts (p. 5)	(Engineering Accreditation Commission (ABET), 2021, p. 5)
EUR-ACE Label (Europe)	**Engineering Practice** The learning process should enable Bachelor Degree graduates to demonstrate: […] awareness of non-technical (societal, health and safety, environmental, economic and industrial) implications of engineering practice (p. 6)	(ENAEE, 2015, p. 4)

Table 2. Examples of social elements in the degree accreditation documents of Canada, Ireland, Japan, the United States, and Europe. Source: Our work

THE ACTUAL INTEGRATION OF SOCIAL ASPECTS IN ENGINEERING EDUCATION

Translating commitments and principles from high-level documents into daily teaching practice is not easy. Few studies include this realisation process in relation to the inclusion of social aspects in engineering education, which is critical in the shaping of the culture of future engineers: Vanderburg & Khan (1994) studied thoughtfully the information available for an engineering degree at the University of Toronto; Cech (2014) surveyed 326 engineering students of four US universities between 2003 and 2008 to detect embedded social awareness in science curricula, and Rulifson & Bielefeld (2019) surveyed 21 students of four US universities for a longitudinal study on socially responsible engineering.

The aim of Vanderburg & Khan was to ascertain to what extent students had gained an understanding during their degree studies of how technology affects society and the biosphere in order to incorporate this understanding into the design of future engineering degrees in particular and practice in general, so as to ensure greater compatibility between technology, society and the environment. The analysis covers lectures, laboratories, textbooks and publications resulting from research work. It had a twofold approach: the analysis of the socially related competences on the syllabuses of science and technology courses, and moreover the analysis of courses on social sciences and humanities to detect whether they convey a satisfactory understanding of the professional practice context to students.

The overall results stress that science and technology courses focus mainly on technology, while social and human science is not necessarily related to professional practice. Engineer education is therefore mainly guided by efficiency, productivity, profitability, cost-effectiveness, and not by information on the degree of compatibility with society and nature, i.e., the ability of engineers to protect society is limited in some extent by their university education (Vanderburg, 2000). It can be said that the overall results are similar to those of current research.

In line with the work of Vanderburg, the studies by Cech (2014) and Rulifson & Bielefeld (2019) show that engineering students' awareness of social aspects is not high and does not improve during their university education; in fact, it worsens. Moreover, social and cultural aspects are perceived to be less important than technical factors. Cech follows the evolution of students' beliefs regarding four aspects of public welfare:

Students' awareness of professional and ethical responsibilities.

The importance of understanding the consequences of technology, i.e., the value given by students to the social implications of engineering design.

The importance attached by students to how people use machines.

Students' social awareness of social development, racial understanding, helping those in need, and being active in the community.

The study also analyses the emphasis in the engineering programme on four social aspects of the profession: social and ethical aspects, the political implications of engineering activities, general education in social sciences and humanities, and writing skills. Cech coined the term "culture of disengagement" to refer to the negative evolution in which the separation between technology and society among students becomes more entrenched during their time in university:

"I argue that despite institutional enthusiasm for nurturing aspiring engineers' engagement with questions of public welfare, the restructuring of accreditation, and a broad recognition that such engagement is important to the role of engineers, engineering education fosters a culture of disengagement that defines public welfare concerns as tangential to what it means to practice engineering" (Cech, 2014, p. 45).

Moreover, another conclusion which may be drawn from her research is that the negative evolution is similar in all cases whatever the emphasis placed by these universities on the social implication of engineering activities. Consequently, the efforts made by universities by means of their educational activities can be neutralised by an adverse cultural context.

Rulifson & Bielefeld focused on how students understand the relationship between engineering and social responsibility and on which factors influence their views. They take a broad view of social responsibility which focuses not so much on social justice as in Cech's work but rather on typical aspects of the engineering profession such as safety, ethical behaviour, or serving clients and users.

The social aspects contemplated by Rulifson & Bielefeld are linked to the social improvement of situations of greater need or vulnerability such as helping people in disadvantaged situations.

Their results show that certain university factors influence the students' views, in particular the introductory engineering courses, work experience at companies, and co-curricular activities such as the *Society of Women Engineers* or *Engineering without Borders*, and also external factors, principally the context and previous culture. With regard to scientific or technological courses the results are ambivalent; some strengthen the connection between engineering and social aspects of engineering, but others weaken it.

They detect a change in academic studies on students' mindsets as to what socially responsible engineering represents, which have shifted from helping society to advance and helping disadvantaged people to focusing on aspects such as safety and engagement with the needs of the company, its customers and its end-users.

An interesting result is the biases created by the way courses are presented. The distinction between micro- and macro-ethics on the course devoted to those subject leads to fourth-year students to consider their responsibility towards their company and employers to prevail over their responsibility towards society.[12]

The current situation in the universities analysed is expressed by the idea that technology is neutral and that there is a clear separation between technological decisions and their social and environmental implications. Engineering activity is considered beneficial in itself as it is a tool for the progress of society. The negative effects of technology come either from the malpractice of engineers, who deviate from the micro-ethics of the profession, or from incorrect use of technology. In both cases the responsibility would be beyond the scope of engineering activities and other professionals would have to deal with such problems. Moreover, they detect a contrast between the official academic discourse and daily teaching activities, as the latter take into consideration albeit in a limited manner the importance of social aspects in engineering practice and the need for students to acquire competences in this area as part of their acquisition of the engineering culture. In fact, they perceive that if interest in social responsibility were greater, more students with special sensitivity to these issues, particularly women, would pursue a degree in engineering and would remain in the profession. Reflexions to encourage the integration of social aspects in engineering education.

Taking into consideration the current integration of social aspects in engineering education and the gap between high-level documents and daily teaching activities, it seems reasonable to consider the need of a change in engineers' education towards a greater commitment to society and the environment. The objective of all this is to ensure that future engineers will be able to extend the beneficial social aspects of their profession and to anticipate and avoid the negative ones. Although this change in the university arena is needed it is not enough and this change must come together with the embracing of this commitment by enterprises and society as a whole. In fact, a change in the culture of society to place human and environmental well-being above economic profit would

12 Micro-ethics focus on aspects such as responsibility towards the employer and the client, cost efficiency, and making correct calculations or sporadic donations, while macro-ethics focus on aspects related to the impact of engineering on society as a whole within a wider context.

be a relevant landmark in a possible transformation process, as society shapes technology in a similar way to how technology shapes society. Society establishes interests and needs in addition to regulations in which engineering activities are embedded.

In order to change the current situation, several issues can be identified from the previous section:

The first issue is the importance of the previous culture which students have acquired before starting an engineering degree. That culture may constitute a significant factor in choosing this degree or otherwise and can create an initial biased perception of the relevance of social aspects in these studies.

Secondly, the need for a greater integration of social aspects in the core competences which a student must acquire, i.e., the social context and the possible impacts of alternative solutions, must be integrated into the analysis of the problem and the designing and development of possible solutions. This must be done by including these aspects in a technological course. As Rulifson & Bielefeldt (2019, p. 964) suggest, "further, integration of ethics and social issues into core engineering and design-focused courses, rather than isolating these topics in dedicated courses, may send a better message that both technical and non-technical issues should always be considered through problem solving and design processes".

And thirdly, the need to review the contents of some courses, e.g., ethics, in order to obtain a satisfactory balance between the micro and macro approaches to ensure that society as a whole is considered in the relationship between technology and society and not only specific stakeholders (clients, supplies, workers). Moreover, it is necessary to define more clearly what is meant by "social aspects" or "social responsibility in engineering". In this sense the ideas and findings of Social Studies of Science can be a valuable source of information.

It is possible to identify three lines of action in the education of engineers to improve their acquisition of competences in order to ensure a better understanding of their role in society and therefore to enable them to study, analyse, design, and develop goods and services with a greater positive social and environmental impact: systemic thinking in engineering, social impact assessment of engineering activities, and public participation in engineering.

THE NEED FOR SYSTEMIC THINKING IN ENGINEERING

As technology is embedded in a cultural, political, institutional and natural context to shape a complex system, a skill on the engineering curriculum which could be reinforced is the ability to adopt a systemic perspective.

The importance of this approach is exemplified in the case of the transfer of technology between different societies (Hughes, 1989). The attributes which a given technology may have do not depend solely on the requirements defined at the time of design but also on the context or system within which it is set and arise when sufficient time has passed. Some of these attributes may evolve over time owing to changes deriving from learning by using adaptations. The generation of a new technological style which differs from that of the original technology is possible depending on the natural or social resources available.

The ability of being able to bear in mind the wide range of all the different interactions that a technology may have within the context of its implementation is not easily acquired as it requires taking into consideration social, environmental, economic and institutional aspects. i.e., the technology is a piece inserted into a system with different intertwined dimensions involving different heterogeneous disciplines. These crosscutting relationships are key elements in systemic thinking, and they are hard to detect and analyse when this approach is not adopted. If the impact of engineering activities is studied with a fragmented perspective in an attempt at simplification for analytical reasons, relevant impacts may be omitted or may be different. Technology may show different properties depending on the system in which it is embedded.

Within this systemic approach it is also necessary to consider the spatial aspect and the timeframe, as technology involves different locations at different stages of its life cycle and different impacts in the short, medium and long term and even in the very long term if future generations are considered. Moreover, the concurrence of different stakeholders is required for a satisfactory analysis and technological judgement.

Systemic thinking broadens the scope of analysis, establishing interrelationships between heterogeneous elements, and allows the improvement of the ratio between the beneficial (positive) and harmful (negative) effects of engineering activities. At the same time, this approach sets a great challenge to engineers, and they must be aware of their limitations when undertaking the analysis of all the relationships of a technology across different dimensions when it is considered as a complex system. The issues to be considered when adopting this approach include the following (Allenby, 2012; Gallopín et al., 2001):

The complexity of interactions between elements in the system with non-linear or circular relationships which make it difficult to establish a sense of causality.

The emergence of unintended and unforeseeable effects of a different nature when applying systematic thinking: positive or negative; short or long term; or local, regional or global. These effects would not be properly anticipated if the analysis of a technology were carried out with different perspectives in an independent and isolated manner. In general, the analysis of a technology from a systemic perspective raises more controversy.

The irreducible existence of uncertainty which means it is not possible to have all the necessary information either to understand the precise operation of the system or to control it; the difficulty of establishing the temporal and physical limit of the system and the presence of delays. The analysis may therefore require permanent adaptation to changing conditions.

The need for finding the appropriate equilibrium between the breadth and the depth of the analysis in a systematic thinking approach.

THE ASSESSMENT OF THE SOCIAL IMPACT OF ENGINEERING ACTIVITIES

Based on the idea that educational institutions and professional bodies proclaim the advantages of the inclusion of the social dimension in engineering professional practice and the value of including the evaluation of the social impact as a planned activity, there is a need to ensure that this approach is put into practice in an effective manner.

An initial step in this realisation process is the inclusion of these topics in the curricula of science and technology courses in university education rather than only in specific courses which are frequently related to the arts and humanities. The latter should focus on analysing the relationship between technology and society and are usually not an ideal setting for a detailed examination of the social dimension of highly specific and technical engineering decisions.

There are interesting proposals to include social aspects in science and technology courses by means of two approaches; value-sensitive design (Davis & Nathan, 2015; Friedman & Hendry, 2019) and socially responsible design (Bissett-Johnson & Radcliffe, 2021; Melles et al., 2011; Rulifson & Bielefeldt, 2019).

The aim of these proposals is to take into consideration all social aspects arising in engineering activities, mainly the resolving of technical challenges, and include them as a further restriction in alternative solutions. This approach should be straightforward since the standard for developing system requirements specifications (*IEEE Guide for Developing System Requirements Specifications*, 1998) mentions the need to consider customer needs, technical aspects, and context. The latter includes political, market, and technical policy and standards and cultural, organisational and physical aspects. There are thus multiple social and cultural aspects to be considered in the definition of the system requirements, which in turn play a major role as they determine the main functional characteristics of the system to be designed.

The inclusion of social aspects in "core" courses of engineering studies would be implemented using social impact assessment methodology (Benoît Norris, C. et al., 2020; Vanclay et al., 2015) in either the design process or project management. This methodology follows similar stages to environmental impact assessment methodology, which is fully integrated in technology activities, but some specific aspects are needed. In this sense both seek to determine the positive or negative impacts of a planned activity whether at a policy, programme, plan, or project level. In a similar way, in both methodologies impacts involve anything which alters in a beneficial/detrimental manner the development of a given community or set of communities within the context of the product's life cycle, i.e., from the procurement of raw materials through manufacturing, distribution, and use to the discarding of the final product.

The inclusion of social impact assessment methodology in science/technology courses in a product/system design could be achieved by introducing a series of questions on the choice of the material to be used in that product/system which combines technical, environmental and social elements, e.g.:

- Does this material have the desired physical properties in terms of strength, conductivity, refractive index, etc.? Does it have the appropriate chemical properties in terms of solubility, reactivity, photosensitivity, etc.? What is the cost of this material?

- Can this material be obtained from recycled sources? How much CO2 is emitted to obtain it? What is the water consumption required to obtain this material?

- Has child labour been used to obtain the material from the mines? Are the miners paid a living wage? Is the material potentially toxic from a perspective of health or human safety?

In the example the choice of the material to be used must meet a number of requirements, which also include social aspects, and may result in the choosing or rejecting of a given material after the analysis. If social aspects are considered from the beginning of the design process, they can reduce the final negative impacts or the costs of their subsequent changes after the design process has been completed.

The inclusion of social impact assessment methodology in science/technology courses on project management would be mainly integrated into the different stages of project development. Firstly, in the initial stage of a project it would form part of the research into the initial problem with the definition of the current situation to be improved and possible alternatives, examining *a priori* possible positive and negative social impacts in a bid to maximise the former and eliminate or minimise the latter. Secondly, at the planning stage, once an alternative has been selected to be implemented positive/negative social impacts may be identified in greater detail; moreover, there is a need for recognising the parties which would be affected if the impacts appear and deciding which action plan should be established to manage these impacts. A Social Impact Management Plan (SIMP) is therefore drawn up at this stage to be used during the next one. Thirdly, in the stage of the implementation of the project the aim is to monitor the evolution of the project by responding to all kinds of impacts. Some are anticipated in the previous stages and included in the SIMP, but others are unforeseen impacts and the action to be taken in this case can significantly alter the development of the project. Finally in the closing stage, once the project has been completed a final evaluation is carried out with the aim of learning from what has occurred during the project and determining the improvements deriving from the implementation of the project.

PUBLIC PARTICIPATION IN ENGINEERING

Public participation is presented here as a specific element to be encouraged in the culture of engineers in university education owing to its relevance as a tool for identifying and managing the impacts of engineering activities, although it could be considered a constituent element of systemic thinking as society is a part of the system. In fact, the public may be conceived as an additional stakeholder to be involved in certain standardised engineering activities, e.g., the definition of requirements (*IEEE Guide for Developing System Requirements Specifications*, 1998) or project management (Project Management Institute, 2017).[13]

Nowadays the management of public participation in engineering activities may vary between two extremes. On one hand, reactive management which considers public participation to be problematic may hinder the successful development of a project, which is the main objective for the

13 The Project Management Guide developed by the Project Management Institute (2017) defines four stages in the stakeholder management process: the identification of stakeholders; the engagement of stakeholders based on their needs, interests, and expectations; the management of stakeholders to handle communication and interaction with said stakeholders to meet their needs and interests; and the monitoring of stakeholder relationships during the project.

engineer and is above any other consideration. From this perspective such public participation should be managed in order to reduce friction, e.g., the hostility of environmental organisations to civil engineering projects.

On the other hand, proactive management considers public participation to be valuable input in a project as stakeholders contribute towards improving its outcome by e.g., providing local knowledge or ideas for its development. The latter approach is especially relevant to major civil engineering projects which may have a major impact on society. In this case, all the parties concerned must have the opportunity to express their ideas and participate in the decision-making process regarding activities which may have a negative impact on their lives. Despite the advantages of public participation, it should be stressed that participatory activities involving citizens and any other third party face numerous obstacles.[14]

In order to encourage public participation in engineering projects, engineers need to acquire the competences to be able to interact with non-technical audiences as a relevant stakeholder of their activities.

14 Gómez González et al. (2008) point out the following type of obstacles to public participation in technology projects: the economic cost and cost in time of developing participatory processes; participation fatigue owing to the large number of projects which would need community involvement; the representativeness of participants with regard to their community; and the refusal of engineers to consider the opinions of lay people as they consider them insufficiently informed for decision-making (cognitive deficit).

COMMUNITY-BASED SCIENTIFIC CULTURE: WAVE OR PARTICLE?

José Manuel de Cózar Escalante; Javier Gómez Ferri

The aim of this paper is to analyse the concept of community-based scientific culture and propose a model for its study. By this expression we refer to situations in which a group of citizens perceive a problem, group together, organise, communicate and pool their resources. In the process, scientific knowledge is sought, evaluated and produced in order to address the problem. Other types of resources and relevant praxeological elements are also generated. The background of the concept is reviewed, a characterisation of the concept is carried out and a model of analysis is proposed with the identification of several phases. The main idea is that scientific culture can be studied at both the individual and the community level, for which the analogy with the wave-particle duality may be useful. How, individually or collectively, scientific culture is viewed and dealt with depends on the case and the objectives. It is important to emphasise that the community scientific culture of a group of citizens is not the aggregation of their individual knowledge and skills but is a property of the whole.

INTRODUCTION

At a quantum level certain entities show dual behaviour, since depending on the study tool used they either behave like a wave or like a particle. By using this analogy, one could say that scientific culture is an entity which adopts either an individual or a collective appearance, depending on the tool used to study it. The context and the tools used to approach its study have made the former, the individual dimension, highly visible while the latter is virtually imperceptible. The situation reflects the trajectory in this field of study as will be seen.

In today's societies, scientific and technological knowledge is of great economic importance to countries and organisations but is also omnipresent in all areas and activities of social life, not to mention its function as a device for legitimising visions of reality. As with wealth, knowledge is also an asset or a resource which is unequally distributed among the members of society. It is yet another element which shapes the social structure and the opportunities and social inequalities of individuals (Polino, 2018). In our societies, there are individuals and organisations rich in knowledge and poor in knowledge; some have more and better knowledge than others. The scientist and populariser Carl Sagan is credited with the statement that "we live in a society exquisitely dependent on science and technology, in which almost nobody knows anything about science and technology". In science, this epistemic poverty, this ignorance or lack of knowledge of which Sagan spoke, is known as "scientific illiteracy". However, as we will see later part of the diagnosed "epistemic poverty" refers to a certain regime of epistemic domination which has given rise to a set of forms of "epistemic injustice" (Fricker, 2007).

Concern for and research into scientific illiteracy developed in the second half of the 20th century when attempts were made to detect it, measure it, and seek solutions. Concepts such as "the public understanding of science", "scientific culture", and the concept which was to become very close to it, "scientific literacy", were established to address what Sagan expressed above, i.e., what people know (and do not know). These concepts also consider science and the individual and social consequences of this knowledge and lack of knowledge. They address the scarcity, the distribution, and the social distribution of scientific knowledge, which is the type of knowledge with more cultural prestige in contemporary societies, despite the recent increase in distrust of and social disaffection with science.

The main objective of this paper is to analyse the concept of scientific culture at a community level or community-based scientific literacy. This expression will be tentatively applied to those situations in which citizens perceive a situation as a problem and group, organise, communicate and pool their resources. In the process scientific knowledge is sought, evaluated, and produced in order to address the problem. Relevant praxeological elements and resources are also revealed.

This chapter will begin with an initial approach to the concept of scientific culture in relation to that of scientific literacy. Then five new scientific and social problems and challenges which arise in the process of redefining the connections between scientific activity, public perception of the latter, and research into this relationship will be described. Subsequently, the relevant background to the concept of community-based scientific culture will be reviewed, a characterisation of the concept will be carried out, and a proposal for a model of analysis will be made with the identification of several stages. The main idea that will be defended is that scientific culture can be studied at both an individual and community level, for which the analogy with the wave-particle duality may be useful. There is a choice of how to view and treat scientific culture, which depends on the case and the objectives. In any case, it is important to show that the scientific culture of a group of citizens is not equivalent to the aggregation of their individual knowledge and skills. Then a brief summary of the main elements of the proposal will be given. To conclude, some of the gaps and aspects which remain to be clarified or examined in more detail will be indicated. The most relevant are those aspects referring to the praxeological dimensions of community-based scientific culture which go beyond cognitive dimensions understood in a restricted sense.

SCIENTIFIC LITERACY AND SCIENTIFIC CULTURE

As has been pointed out, the alleged problem of the lack of knowledge of science among citizens has been a major concern in developed countries, particularly in the USA, since the late 1950s. This concern led to the implementation of a series of educational initiatives with the aim of promoting a more even distribution of scientific knowledge in society (Gregory & Miller, 1998). These initiatives led in the late 1970s to two academic-educational programmes: one of "scientific literacy" and the other of the "public understanding of science". In the latter "scientific culture" has become one of the central concepts because it is more comprehensive and has a more descriptive and less normative and cognitive orientation than "scientific literacy". Although both concepts have a long history dating back to the early 20th century (Gómez Ferri, 2012), as is synthesised by Laspra (2018: 27), the concept of scientific culture does not develop from that of scientific literacy but rather builds on its critique.

In this respect it should be made clear that the expression "scientific culture," in its most widespread and accepted definition, does not refer to the term "culture" in an anthropological sense but rather in a "humanistic" sense. In other words, it refers to the knowledge and tastes which lead to a person in a society being considered cultured or uncultured or well-informed and educated or the opposite. This is a different sense from the term "culture" when it refers to social and cultural anthropology, which is much wider and more comprehensive. The humanistic sense contains and expresses a hierarchical and normative conception of knowledge (Gómez Ferri, 2012). The use of the term “culture” in an anthropological sense goes beyond the question of the value of knowledge and how it is distributed in society. This anthropological sense understands knowledge as a set of practices of being in the world and giving it meaning. By analogy with the communities studied by anthropologists, it alludes to a set of norms, beliefs and practices shared by a group or community, the "tribe" of scientists (Gómez Ferri, 2012). In this sense, the most accurate expression is "science culture", i.e., the culture of the scientific community (or scientific communities), although as it is not uncommon to see this expression used interchangeably with "scientific culture" the terminology may cause some confusion (Vogt, 2003; Quintanilla, 2010; Claessens, 2021).

"Scientific culture" in a humanistic sense and "scientific literacy" are thus two key elements of the scientific study of what people know, do, or think about science, i.e., of citizens' knowledge, skills, behaviour, and attitudes to science (and technology).

In societies of knowledge with democratic political systems, both the promotion and development of science and technology and in addition the achieving of a certain familiarity and appreciation of the latter by citizens constitute a challenge for public policies and are of undeniable interest if cultural indicators are to be obtained. The surveys commissioned by the National Association of Science Writers (NASW) and carried out by the University of Michigan in 1957 in the USA laid the foundations for the first public perception studies on science and technology. This initiative represented an attempt to measure the scientific literacy and culture of the American population (Davis, 1958). Public perception surveys were not taken up again in the USA until the late 1970s and shortly afterwards were carried out in many other countries. However, in this initial period the foundations were laid for a theoretical model that of the "cognitive deficit", which is precisely what is reflected in Sagan's previous diagnosis.

The deficit model establishes the existence of a linear association between scientific knowledge or literacy and attitudes towards science. The less knowledge and less familiarity with science, the more rejection and disinterest; the more knowledge, the greater the acceptance of science. This model was a result of scientists' own perception and concern rather than being supported by the existence of data. It was based on the concern about a possible generalisation of disaffection with and even hostility towards science deriving from the public's lack of scientific knowledge. It was allegedly detected in the late 1950s in the context of the so-called "cold war" and more specifically the space race between the USSR and the USA.

This is a simplistic and simplifying model which has predominated for a long time, especially in the carrying out of science communication and popularisation activities, even though the data and results of empirical research do not confirm it. Nevertheless, it has served to sustain and legitimise an extensive programme of the dissemination of scientific culture focusing on the concern about the governance of science. On the one hand, this programme has shown the existence of a certain level of panic in the rush to produce "a more scientifically literate citizenry, capable of actively participating in the resolution of controversies related to science and technology" (Muñoz van den Eynde, 2014). On the other hand, it has been partially separated from studies of scientific culture, which have dealt with the relations between science and the public (López Cerezo, 2017).

Academic interest in science and public relations is somewhat more recent than the study of and reflection on epistemological, sociological, and historical questions about science. Despite this, in just over six decades since the late 1950s (Laugksh, 2000) a rich, varied and powerful interdisciplinary field has emerged, that of science communication and the public understanding of science. In all this time there have been significant advances in the theorisation of its central objects (namely scientific literacy and scientific culture). Progress has also been made in empirical research and in the practices of science communication and popularisation.

This evolution could be summarised very briefly by commenting on the main areas of research. On the theoretical side, the characterisation and definition of "scientific literacy" and "scientific culture", two concepts which have been converging in the process, have been refined. In this manner both concepts have become more precise, rigorous, and comprehensive. In addition, they have been moving away from the school bias of the initial period (Pardo, 2014). A conceptual apparatus capable of better describing and explaining the reality of the diverse and complex relationships between science and the public has been developing. To be more precise, it would be more helpful to talk of the relationships between different sciences and different publics (de Cózar Escalante & Núñez Castro, 2018).

In the carrying out of research, the operationalisation of core concepts has reached an acceptable level of refinement, which means that solid measurement instruments have been established in empirical research, either to describe the phenomena involved or to formulate theories and explanatory models in rejection of the initial deficit, passive, and unidirectional model (Pella et al, 1966; Shen, 1975; Miller, 1983, 1998; Bauer et al, 2000; Roberts & Bybee, 2007; Godin & Gingras, 2000; Bauer, 2014). This process of operationalisation has been the result of collaborative work at an international level which has produced indicators allowing both transverse and longitudinal comparisons within countries.

In any case, in the process of international standardisation one should avoid the trap of the conceptualisation of scientific culture in terms of a sporting competition, to see who comes in first and last, an approach which judges countries or individuals (National Academies of Sciences, Engineering, and Medicine, 2016: viii). We must also avoid losing the ability to capture ethnic, regional, or national particularities owing to the preponderance of quantitative survey techniques.

Finally, throughout this period of time there have been profound social changes which go beyond the very field of scientific study being discussed here. Basically, as society has changed the roles and relationships between science and its publics it has also been reshaped. This is especially evident in the changes observed in the attitudes, perceptions, and practices of citizens with regard to science. The model of an ignorant, passive, and uncritical citizen, in addition to the paternalistic, elitist and technocratic relationship of the initial period, is losing ground. In its place we are seeing the emergence of the perception of a more active, critical, involved and participatory citizen both individually and collectively. It is a dynamic in which the boundaries of the relations and divisions between laymen and experts are more open and fluid (House of Lords, 2000; Jasanoff, 2003; López Cerezo, 2005; Lengwiler, 2008; Cortassa, 2010; Pardo, 2014). Civil society has been incorporated as a new agent in the (co)production and dissemination of expert or scientific knowledge, thus breaking the monopoly and scientific hegemony of so-called experts. This new point of view calls into question, although it does not reverse, the traditional cultural order and hierarchies based on the divisions of the production and possession of knowledge.

NEW PROBLEMS AND CHALLENGES

This cultural change is synthesised in the three paradigms identified by Martin W. Bauer, Nick Allum, and Steve Miller (2007) in this whole process. As the three paradigms correspond to a certain temporal sequence, it would be better to understand them as ongoing research programmes with different levels of implementation: scientific literacy, public understanding of science, and science and society. As society and research into science-society relations are changing, new problems and new scientific and social challenges are emerging. Five of them will be briefly mentioned below. The last one is the subject of this paper.

First of all, with regard to the cultural divisions operating in the field of knowledge, we must be aware of the fact that hierarchies, dominations, marginalisation, and exclusions also occur within science. There is a hierarchy between on the one hand the natural and biomedical sciences to which mathematics must be added, which are identified without further ado as "science", and on the other hand the social sciences. These need the qualifying adjective, as if they were not sciences at all or were inferior or second-rate sciences (López Cerezo, 2005).

Secondly, there is an exaggerated predominance of descriptive empirical research which is separate from the explanatory pretensions of theoretical formulation. The reason for this may perhaps be found in the fact that the field has been shaped more by external institutional factors of a practical and political nature which are directly related to interests in the communication and dissemination of science and the obtaining of public indicators (Pardo, 2014).

Thirdly, in spite of a certain evolution in studies on scientific culture and literacy, the observation and measurement of conceptual or cognitive dimensions (i.e., "knowing what, as well as attitudinal dimensions") continue to predominate. What people actually do is left in the background. It is not merely a question of having knowledge of science or not and valuing it positively or negatively, but also of using scientific knowledge and putting it into practice. Erudite or encyclopaedic bias is also maintained when studying and evaluating the praxeological dimensions referring to scientific method and to science as a system and social institution (López Cerezo & Cámara Hurtado, 2009; López Cerezo, 2017). It is not about knowing about science or knowing what the scientific method is and how science works. It’s a matter of behaving and making decisions based on a scientific understanding of phenomena, even participating in the production of scientific knowledge.

Fourthly, the greater integration of culture and scientific literacy with the remainder of the cultural facets of the social actors is also lacking. Scientific culture is often treated in isolation and decontextualised with regard to the set of interests, attitudes and cultural practices of the subjects studied. It is detached from culture as a greater totality in which that aspect is integrated (Irwin & Wynne, 1996; Godin & Gingras, 2000). In the words of Martin Bauer –in conversation with Bruce Lewestein- it would be "desirable to obtain a more realistic picture of the situation of science within the total portfolio of interests of people's daily lives" (Bauer, 2014: 121).

Finally, this "isolationism" and the approach to culture and scientific literacy (up to a point related to the above) have followed an individualistic ontology and methodology. They have been studied as if they were a natural attribute of the subjects (Godin & Gingras, 2000, Roth & Lee, 2002, National Academies of Sciences, Engineering & Medicine, 2016). The unit of analysis has been the individual, an isolated subject, who is later statistically allocated to a category (sex, age, level of studies, country, etc.). This orientation is a kind of dogma which has hardly been questioned since the initiation of programmes on the public understanding of science, scientific literacy, and scientific culture (Roth and Lee, 2002:34). However, individuals learn from and with each other in both formal and informal interactions. Culture and literacy are relational. In some cases, it can even be viewed and studied as a phenomenon which is a property of groups or communities as such. Therefore, the question here is whether scientific culture is really only an individual attribute or whether it is seen to be so owing to the double effect of the cultural individualism of institutions and the values of late modernity. This effect is empowered by the predominant technique of social research in this field: the survey. For this reason, this paper examines whether scientific culture also has a communitarian aspect as a body of knowledge, evaluations, and practices produced and shared by a group. This would be a relevant dimension of scientific culture that has perhaps gone unnoticed too often among scholars of the subject.

After having pointed out that one of the most significant gaps in the field of research into scientific culture is the fact that it has been treated and studied only as an individual attribute, it is proposed here that on certain occasions it may be useful and realistic to study scientific culture as an objective of certain social groups. This is not so much a result of its high level of sharing but rather because of the level of participation and community involvement in the internalisation and production of knowledge. To this end a set of previous studies on the subject will be identified and a model of analysis of community-based scientific culture will be proposed.

BACKGROUND AND ELEMENTS FOR THE ANALYSIS OF COMMUNITY-BASED SCIENTIFIC CULTURE (CBSC)

In their report entitled *Science Literacy: Concepts, Contexts, and Consequences,* the National Academies of Sciences, Engineering, and Medicine (2016) warned of the possibility that certain relevant aspects of the reality of scientific literacy are being overlooked or at least minimised. Among other matters, the report highlights the fact that scientific culture may be not only a property or attribute of individuals but also of groups in a substantive sense. In other words, it is a reality that can be treated as an object of study in itself rather than being approached as a mere addition to the personal scientific literacy of individuals.

Although the idea is not new, it has so far undergone little specific development in the field of the public understanding of science. The number of studies in this line of research is very small and has no continuity over time (Roth and Lee, 2002; Roth, 2003; Lee & Roth, 2003; National Academies of Sciences, Engineering, and Medicine, 2016).

However, both theoretically and empirically and also from different areas and academic disciplines, there are precedents, bases, and results which offer the possibility of approaching scientific culture as a community entity and not only as an individual one, as has been the case up to now. From a temporal point of view, up until the 1980s contributions to the subject were scattered and rather indirect, while since the end of that decade they have been more focused.

To begin with, the existence of a shared cognitive dimension can lead us to think of classic concepts in sociology and social psychology such as "collective representations", which was proposed by Emile Durkheim to discuss thought and knowledge. Decades later it was taken up again by Serge Moscovici (1961) under the reformulation of "social representations" and specifically applied to the case of how psychoanalytical ideas and terms have passed from a specialised field to become a subject of interest to the general public. When he mentions "social representations" Moscovici is referring to knowledge. Common sense knowledge is not excluded; it is understood as a knowledge which is produced and arises from social interactions in everyday life. It takes the form of an organized corpus of shared knowledge which gives intelligibility to reality. The difference between the concepts we are dealing with may lie in the scope and extension of the objective. In the case of community-based scientific culture (CBSC) therefore, we would be dealing not so much with the knowledge and common sense of society or of a large group but rather with the knowledge, values, practices, and other resources of small groups and in very specific fields of knowledge. This kind of knowledge could remind us of the thought group ("Denkkollektiv") mentioned by Fleck (1935) or the communities of practice of Peter Haas (1989), and also of the epistemic communities of Jane Lave & Etienne Wanger (1991).

Together with social psychology, in the social epistemology proposed by Steve Fuller (1987), some works by Alvin Goldman (1987), Helen Longino (2002), and Michael S. Brady and Miranda Fricker (2016), both from social studies of science and from philosophy, the social nature of the production and collective justification of knowledge is highlighted. Those approaches are linked to the broader tradition of the sociology of knowledge as a field of study of the formation of beliefs. From both traditions (social studies of science and philosophy) there have been several contributions which have highlighted the institutional dimension of knowledge. They have also stressed the cognitive mechanisms of the construction of social reality and its links with contextual causal factors focusing attention from groups of thought to the social structure itself (Fleck, 1935; Merton, 1938; Kuhn, 1962; Berger & Luckmann, 1966; Foucault, 1966; Bloor, 1976; Knorr-Cetina, 1999). CBSC would reveal among other matters the connection between the problems and needs of social groups, their practices, and the mechanisms of the creation of knowledge.

It is not simply a case of identifying and pointing out the factors which link social contexts with the beliefs of individuals and their practices or remembering that we acquire information and knowledge essentially from others, which is quite obvious. Some specific knowledge is the result of cooperative and shared activity within groups and of joint evaluation. In this sense, Ikujiro Nonaka and Hirotaka Takeuchi (1995) have dealt with these issues from the perspective of knowledge management; being positioned closer to the concept of CBSC they have defended the existence of organisational knowledge. This knowledge is created or produced within a certain group, by the group, and to some extent for the group. It tries to respond to a collective problem and intends to redefine or solve it. In the case of CBSC this organizational knowledge would not only point to the group itself but also to the reality with which it interacts. It would have the additional aim of projecting itself outside the group.

The increase in and facilitating of connectivity and interactions permitted by the new information and communication technologies have been strengthening and giving precision to the idea that there can be collective thinking and intelligence as postulated by the so-called theory of collective intelligences by Pierre Lévy (1994; De Kerckhove, 1995). It is a fact that it would be greatly facilitated by social communication networks. Networks of distributed intelligence exist which have the capacity of interlocution with experts. These networks can also broaden the perspectives of analysis and enrich the approach to the issues being investigated. This improvement can occur even at a more specifically technical level. Although it is not an essential factor, the existence of a technological environment which allows the communication exchanges facilitates not only the creation and sharing of knowledge but also links between people and between social groups. As this is precisely what occurs with CBSC, a significant increase in the number of cases in the last decade which are consistent with this dynamic is therefore to be expected.

Finally, the community dimension of scientific culture could be usefully approached from the conceptualisations proposed, by Peter Haas, Jane Lave and Etienne Wanger respectively, from a community perspective, either as "communities of practice" (Haas, 1989) or as "epistemic communities" (Lave & Wanger, 1991). In doing so, Lave and Wanger in particular have highlighted the practical dimension of collective learning processes and the production of expert knowledge based on shared experiences and joint analysis of information in small and medium-sized social groups. While in the concepts of "communities of practice" and "learning communities" the emphasis is on the group and the action, in the concept of CBSC the emphasis is rather on the product of this communal action. On the other hand, it is clear that the product of a community of practice or learning community will not always embody CBSC. Such a product may not be scientific in nature, but as far as CBSC is concerned the groups would be communities which would produce such an outcome (i.e., scientific and technical).

There is a diversity of empirical and social practice studies which have highlighted the community dimension of scientific knowledge but have not however received sufficient attention. To begin with we have the whole tradition of popular epidemiology in which lay people detect and act on environmental or occupational hazards and diseases (Brown, 1992). A widely-cited example is the case of Love Canal, a neighbourhood in Niagara Falls, upstate New York (Levine, 1982; Nash & Kirsch, 1986). Another is Woburn, a small town north of Boston where an abnormal number of cases of childhood leukaemia were detected. With this type of problem detection is often the result of research and mobilisation by local citizen groups rather than by experts and institutions.

Sometimes cases of popular epidemiology may straddle two more researched fields: on the one hand collective action and social movements (Hess et al, 2008; Corburn, 2005) and on the other, community-based participatory research or participatory action research in which the members of a community are involved in all aspects of the research process, contribute their knowledge, and share in decision-making (Balazs & Morello-Frosch, 2013). Citizens thus pass from constituting objects of study to becoming subjects of the research, overseeing the process and interacting in its different stages such as design, proposed actions, etc. (Villasante et al, 2000). The subject of the research is a non-academic group which actively participates from the outset in the production of knowledge and in the defining and follow-up of the programmed actions. As far as collective action and social movements are concerned, such dynamics often involve collaborative work by groups of citizens on the management, production, and evaluation of knowledge. Citizen mobilisations may be a response to conflicts over expert knowledge, to the harmful effects of scientific and technical developments or applications, or to the defence and conservation of certain natural spaces. This is also the case of the long list of projects which are embedded in participatory action research when the project revolves around scientific or technical issues. These two areas provide a wide range of cases in which scientific culture reveals its community character in addition to its practical character. Certain well known cases from the social studies of science are relevant in this regard, such as associations of patients and sufferers from various diseases (Rabeharisoa & Callon, 1998, 1999, 2000, 2002; Rabeharisoa et al., 2014; Callon & Rabeharisoa, 2008). The controversy over AIDS treatments during the early years of the identification and countering of the associated epidemic is also well known (Epstein, 1995). In addition, more recent studies on the role of individuals and groups of people affected by Long COVID are of great interest (Callard & Perego, 2021; McCorkell et al., 2021; Perego & Callard, 2021).

A common feature of many of these cases is the working in cooperation of people who are not scientists, i.e., laymen as far as science or technology are concerned. They become aware of a problem and use collective resources to search for and manage scientific information which is sometimes difficult to access or make available. Moreover, they are able to produce relevant knowledge –which experts have not produced– in order to address and solve the problem which concerns them, thanks to the social, scientific and technological resources available. In this regard it is worth mentioning the activism and social movements which are active in the field of health, environmental surveillance and monitoring or the aforementioned "popular epidemiology". These are interesting examples of communities capable of generating scientific culture in the sense suggested here. Furthermore, all these cases highlight the social mechanisms of the legitimisation/delegitimization of knowledge produced by laymen. As social studies of science have highlighted, these phenomena are related to the existence of epistemic barriers, hierarchies, and inequalities between the types of knowledge produced by experts and non-experts (Wynne, 1998; Collins, 2014; Fricker, 2007).

To conclude the list of areas in which cases of CBSC occur, the recent rise of citizen science provides many examples. The manifestations and forms of citizen science are diverse (Gómez Ferri, 2014). Despite this, certain activities carried out by groups of people (in particular enthusiasts of some kind of scientific activity or active participants in a multiplicity of scientific projects) constitute further evidence in favour of the existence of the phenomenon we are considering: an entity that transcends individual resources and contributions, a reality that is practised and configured communally.

From the cases mentioned in this section it is clear that there are numerous theoretical and empirical background aspects exist which allow us to discuss and address the existence of CBSC. The focus of attention should not therefore fall on an ontological debate. As in the case with quantum particles, it is no longer so much a question of determining whether scientific culture is an attribute of individuals or of groups but of whether it can and should be treated and studied in both ways. The key question is rather that of the type of perspective in recognising the situations in which it is better to approach scientific culture in one way or another. To take up the analogy in the title of this study, it can be approached as a wave or as a particle. It is even possible that on occasions it is wise to study it in both ways. There are methodologies and techniques for studying CBSC. However, a conceptual framework for carrying out such research in a sufficiently systematic way has not yet been developed. In the following section we propose some elements which may contribute to the development of such a model for CBSC.

THE CHARACTERISATION OF COMMUNITY-BASED SCIENTIFIC CULTURE

Gaps exist regarding CBSC which need to be filled in, namely its recognition, identification, conceptualisation, operationalisation, and empirical study. As an initial approximation, CBSC can be understood as a social practice which comprises a series of resources (knowledge, skills, abilities, practices, and methods of a scientific, technical or expert nature) possessed, distributed, obtained, organised and shared by the members of a community, so that said community is in a position to carry out the necessary action to try to achieve the objectives it has set for itself. The interactions between the participants and the members of the community generate resources which exceed the sum of individual contributions. They therefore give rise to situations and processes in which the community as a whole reaches an empowering position. Thus, the creation or production of CBSC (and even of new scientific knowledge) does not constitute the mere sum of the contributions of individuals. The starting point is not necessarily the same capabilities or the same contributions from all the members of the group, but the individual differences are less relevant than what is shared. For this very reason, it can be argued that CBSC is not a phenomenon reducible to individuals and their individual actions.

Analytically, the elements involved in this proposed characterisation of CBSC understood as a social practice are as follows (clarifications and terminological suggestions are given in brackets):

The series of resources (knowledge, skills, abilities, practices, and methods) of a scientific, technical or expert nature, possessed (shared) by the members of a community group,

the synergies and interactions of which (the cooperation and complementarity which form the group or community and its distribution and organisation)

give rise to situations and processes in which the community as a whole achieves a position (a shared, strong, empowering and enabling position) which

Is qualitatively and quantitatively superior to the resources of the individuals which make up this community (which transcends the simple accumulation of individual contributions; emergent properties are generated which are possessed by the group as an agent rather than by the individuals it consists of)

in order to interact in a complex and effective way (discussing "matters of concern" and possible solutions, increasing their capacity for dialogue, promoting and carrying out social initiatives, implementing "collaborative design" processes) with experts, professionals, technicians, scientific and health institutions, public authorities (the capacity to lobby the administration) and other relevant public and private players

and to contribute to scientific knowledge (scientific progress) and to the resolving of technical or expert problems.

To summarize the above, the existence of a dynamic which could be described as a generator of CBSC depends on the community:

Having scientific resources (knowledge, skills, abilities, etc.), or being otherwise able to acquire them or generate them. According to Pierre Bourdieu's theory (Bourdieu 1986, 1994) this set of resources can be understood to be a form of cultural capital but is not limited to cognitive aspects. It also contemplates axiological and above all aspects of collective practice in the form of mental and behavioural dispositions which nevertheless are not exclusively included in the ways in which cultural capital manifests itself. For Bourdieu it is institutionalised, objectified, and incorporated. In this case the cultural capital would be not only consist of information but also and especially of a set of practices to obtain, select, evaluate, and legitimate a set of data and scientific information which is generated in the process of interaction within the group, and which emerges in a novel way. These are knowledge practices which can be understood and analysed as a type of practical awareness of the practices of knowing acquired by social actors; and in this case of knowing as it occurs in science.

Sharing these resources, distributing them, and organising them efficiently thanks to the creation of a network of relationships and interaction practices; from the perspective of Bourdieu's theory of capitals this would be generated due to the existence and production of a social capital (Bourdieu, 1980). It is a network of exchanges through which material and symbolic resources circulate to transcend the community itself, since in these cases the groups created not only generate synergies and interactions within the groups themselves but also with other groups, agents, and social institutions. Social capital should not be seen as something exclusively limited to the group or community in question. Social capital is a resource which is not strictly cognitive, but through which cognitive, affective and symbolic resources circulate, whether favourably or not, and which translates into actions and public or social mobilisations which may or may not favour the objectives: achieving symbolic capital. Being well or badly related reinforces or reduces the credibility of the group, its cognitive products, and its actions.

And through its commitment to community action, being in a position to carry out the necessary actions to try to obtain recognition of the jointly produced knowledge, i.e., legitimacy. From Bourdieu's perspective (Bourdieu, 1986; 1994) this would take the form of symbolic capital, which is no more than a cultural capital which is known and recognised and therefore a power and empowerment deriving from the social recognition obtained.

It is important to emphasise that the characterisation of CBSC proposed here underlines its praxeological dimension and would therefore be accessible, in principle, to a systematisation in praxeological terms. CBSC is a type of social or if one prefers communitarian praxis. The products generated are not only shared theoretical knowledge, i.e., knowledge with a greater or lesser degree of abstraction. The existing social practices which are brought into play, in addition to the new practices emerging during the process, are essential to this approach. Some are instrumental, so to speak, and necessary for the achievement of the objectives. For example, this would be the case of computer skills at the service of an efficient search for information and the consolidation of the communication and exchange network of the community, and also familiarity with the procedures of the production and validation (or invalidation) of knowledge which scientists put into practice during their professional activities. Other practices are valuable in themselves by modifying the behavioural dispositions of the members of the group to adjust as far as possible to the knowledge obtained and to the ways in which the perceived problem can be solved according to the criteria of the community. These may adopt an infinite number of specific forms: following preventive and hygienic measures; choosing some foods or materials and rejecting others; promoting changes in cultivation, building and mobility patterns; trying new ways of relating to others, changing work habits, transforming experimental protocols for testing new drugs, and so on.

In the words of Reckwitz, these and other possible modifications of the behaviour of the community members which are transformed into social practices become routines in which a series of interconnected elements are involved: bodily activities, mental activities, objects and different forms of knowledge, symbolic elements (such as meanings), and practical knowledge and skills, in addition to emotions and motivations. “Practice […] forms so to speak a ‘block’ whose existence necessarily depends on the existence and specific interconnectedness of these elements, and which cannot be reduced to any one of these single elements" (Reckwitz, 2002, p. 249-250).

PROPOSAL FOR ANALYSIS

In order to give a more operational character to the previous characterisation of the concept of scientific culture and to propose it as a model of analysis, the three dimensions implicit in this characterisation have been developed as stages of a process. An initial element has been added. More importantly, this is proposed as an interactive process in which a set of scientific, technical or expert resources are generated, shared and put into practical use. It should be noted that although they are presented as stages succeeding one another, their sequentiality should not be taken at face value. Throughout the process there will be dynamics which may involve two or more stages at different levels of "development". There may even be a real or apparent "regression" in some of the dynamics involved (which reach what would be a supposed end point in terms of the development of the stages) only to give rise to a new process from the point reached.

The starting point of the model (the "initial stage") is the double ontological game which is played between the existence of a problem and perceiving it or not perceiving it. In this first stage a double situation must occur: the perception of the problem and the awareness that it is not individual, but common. This awareness gives rise to the creation of the group or future community (with a greater degree of internal cohesion). Without this initial perception and awareness, the shared knowledge and the remainder of the elements generating true CBSC will not be produced (de Cózar Escalante & Núñez Castro, 2018). The empirical work must be oriented towards knowing when and how awareness of the problem arises and also the possible influence of other stakeholders and media in this process.

In addition to being affected by or concerned with the problem in a fairly direct way, the group usually shares a cultural context involving space or territory. However, in today's society in which new means of communication have facilitated contact and links between geographically distant individuals, the territorial element can be combined with the "virtual" or "media" space.

In this respect it is interesting to note that the problem manifests itself in a dual manner: a) as recognition of the fact that a person or group is being affected, which implies current or future damage, and b) as recognition of a lack of knowledge (or simply of plain ignorance) of the way in which the problem affects people. Obvious examples would be a rare disease, an element harmful to health, or a new syndrome. In order to address both aspects, a complex activity of visibility, sensitisation, and the raising of awareness is set in motion. In this way assets are incorporated, and the size of the group is established or increased. Without this dual element (the perception of the problem and the creation of the group) it will not be possible to produce the shared knowledge inherent to CBSC.

When we think about CBSC according to this characterisation, we imagine a pre-existing community (for example, the inhabitants of a village) which has to face a problem affecting it; or a group which is generated precisely from the perception of a shared problem (the example of a patients' association). In this sense it would not so much be a question of invited participation, understood as an invitation extended by public authorities or private players to citizens and civil society to take part in a participatory experience following pre-existing methodology. The group rather takes a step forward without waiting to be invited, so to speak, and self-organises in order to demand to be heard and have its demands addressed, such as obtaining knowledge of the illness afflicting its children or dismantling a dangerous installation near its homes. In other words, many cases of CBSC do not correspond to vertical participation promoted "from above" but to horizontal participation. In the latter case, the aim is for it to be on an equal footing among the individuals of the group and among all the players involved. However, it is interesting to think of cases in which neither one situation nor the other occurs; these cases are "hybrids". In other words, they are the result of the merging on the one hand of certain community movements demanding participation in the resolution of a problem and on the other of institutional (or private) initiatives which seek to encourage such participation through established channels. In this intermediate terrain, some dynamics can be generated which are particularly worthy of careful study. A recent case which appears to fit this hybrid typology and which for obvious reasons is of great social relevance is research into Long COVID (Callard & Perego, 2021; McCorkell et al., 2021; Perego & Callard, 2021). There has been a shift from an initial situation of the "invisibility" of those affected and their frustration at not being heard to widespread awareness of the problem and recognition of the situation of those suffering from Long COVID since the beginning of the pandemic and throughout its evolution. In some significant cases health professionals, researchers, public decision-makers, businesspeople, and patients have met halfway, as it were. The implementation of a variety of collaborative research projects, such as the initial statistical studies which have benefitted from the impetus and the active participation of numerous patients' associations, has been a key part of this process. From the starting point of "uninvited participation" this has led to invited participation, or to be more precise, to a peer-to-peer collaboration between all relevant actors.

The second stage has two dimensions which are indissolubly intertwined but can be broken down analytically in order to be studied. The first of these revolves not only around the use and mobilisation of a set of cognitive resources from both cultural and social capital (knowledge, skills, practical abilities, and scientific methods) which are already possessed by the members of a community but also around the search for and production of new resources. Among the resources possessed and often unrecognised (in a double sense) are those of prior local and tacit knowledge and also personal experiences. They therefore include cognitive resources and knowledge and practices regarding the matter or problem (the resources are useful for obtaining and evaluating this knowledge in addition to organisational resources to constitute and organise the group). All this is without yet mentioning the maximum deployment of mobilisation and action. The main aim at this stage is to make visible, draw attention to, denounce, identify, and locate alternative information resources about which the establishment of alliances and collaborations with other associations and groups can be decisive. Research focused on this dimension must examine the players' previous knowledge, assessments, and practices and how they have been obtained. Subsequently it must go on to deal with the ways in which new shared knowledge is sought by selecting, validating, or discarding what has been obtained. In the case of Long COVID for example, the first diagnoses which patients were given from health professionals were questioned and sometimes rejected based on the knowledge, practices, and evidence which the patients themselves were producing.

The second dimension of this second stage concerns the maximum deployment of action and mobilisation organised around cognitive resources. It could be said that cultural capital becomes so because it is socialised in the sense that it is shared. Social capital makes it possible to shape what formerly consisted of fragmentary practices and partial and individual knowledge. Concerning this stage, research has to deal with the number of members making up the group, their different levels of involvement, and their contacts with other agents and groups, in addition to the channels of the communication and circulation of information, group activities, the ways in which information is discussed, and also the mobilisations and the visibilisation or protest actions carried out. In the case of Long COVID, the process of grouping in networks and associations at different levels of institutionalisation of what were initially isolated individuals fighting individually for the recognition of their situation can be clearly observed. Social networks have played an essential role in the process, providing an invaluable platform for sharing experiences but also for making proposals for research and treatment projects. A crucial set of activities were aimed at obtaining greater visibility in the media and for the general public on a community, regional or national scale or even on an international scale (Callard & Perego, 2021; McCorkell et al., 2021; Perego & Callard, 2021).

Finally, the third stage concerns the outcome of the learning and research processes and the possibility of providing a new vision or definition of reality. New knowledge of the problems posed is associated with novel and more appropriate forms of behaviour in order to solve or minimise the harmful effects involved in such problems. It is equally important to provide solutions with a sufficient degree of legitimacy in the face of the lack of knowledge or the limitations of pre-existing knowledge. As a result of the process, the community achieves a position which enables and empowers it to carry out effective action and “response plans”. In Bourdieu's terminology, cultural capital is transformed into symbolic capital partly with the support of social capital. What is important is the competence to produce knowledge and the associated practices which this knowledge entails. It is not merely a matter of knowing science or appreciating it. It is all about knowing how to do science, i.e., controlling (or at least being familiar enough with) the procedures of the understanding, appreciation, validation, and communication of science as a form of social participation. It is all about the social appropriation of science in a true sense since the knowledge obtained is "internalised" and made use of to eventually modify behaviours, not so much in an individual sense (as a personal possession, so to speak), but in a community sense. Research into this third step should identify the knowledge produced, significant changes in behavioural dispositions, and perhaps most important, the legitimation mechanisms and strategies used.

In the case of Long COVID, a great deal of knowledge has been generated about the problem, issues requiring further research have been identified, and results have been legitimised. Many of these results have been generated by a collaborative effort of all the players involved on an equal footing. It is worth noting that the behaviour of those affected by Long COVID has changed in the way they care for themselves and are medically treated and also in the way they relate to other groups, whether or not those groups consist of people with Long COVID (in some cases a single individual has been both the researcher and the patient). Although this is a long-term struggle, it is undeniable that the perception of the legitimacy of the patients’ groups by authorities and experts has also changed for the better in the way these groups and their members are treated. The knowledge produced and the dialogue of the patients' groups and associations has meant that they earn their epistemic and political legitimacy through the effectiveness of their organisation and actions. In short, all this has led to increased recognition of Long COVID groups by communities of experts and institutions (Callard & Perego, 2021; McCorkell et al., 2021; Perego & Callard, 2021).

EPILOGUE

Despite its undeniable interest, the concept of community-based scientific culture (or scientific culture at a community level) has not been sufficiently addressed and developed in the academic literature. In this chapter, an initial contextualisation of the field is provided, together with the identification of a series of problems and challenges to be addressed. Then a kind of archaeological task was carried out to reveal an extensive series of academic studies which could be identified as pioneers or at least be considered relevant to a rigorous and updated approach to the concept at hand. The variety and heterogeneity of academic traditions and research with results which are extremely helpful in clarifying the concept of CBSC is remarkable. To give just one example, it is worth mentioning Pierre Bourdieu's theory on the social, cultural, and symbolic capitals, which has been referred to in the last sections of this chapter.

After revising the background, a tentative characterisation of the concept of CBSC has been proposed in addition to a model of analysis based on three main stages. Both the characterisation and the model can be useful when describing any process suitable for approximation from a CBSC perspective.

However, much remains to be done. An adequate understanding of CBSC requires multiple contributions to facilitate its recognition and identification, conceptualisation, operationalisation and empirical study. Numerous case studies are also required to test the proposed models and readjust them where necessary. It is also vital to highlight and improve the specifically praxeological aspects of CBSC, i.e., to go beyond data and studies on what people know about science and technology to what people do when they practice or are familiar with science and technology. This kind of research will certainly lead to relevant and valuable results.

To return to the physical analogy so as to conclude, it is important to show in each case (such as the observation of a phenomenon as a wave or a particle) how the individual/community methodological choice in the study of scientific culture responds to well-argued epistemic and practical justifications.

PRAXEOLOGY AND SOCIAL ASYMMETRY

Carmelo Polino

The praxeological dimension is a constant in the conceptualisation of the scientific culture. Being interested, informed, gaining knowledge, being willing to be involved and participate as a citizen are forms of practicing science. Additionally, what we do (praxeology) can influence what we know (cognition) and what we value (axiology) about science and technology. However, scientific culture models have delved rather little into the fact that what we know, value and do depends to a great extent on our social identity. The opportunities to practice science are asymmetrically distributed in society. Praxeology and social asymmetry are the focus of this chapter. First are reviewed some of the outstanding contributions to the conceptualisation of the scientific culture, placing special emphasis on the praxeological dimension. Next it is posed the problem of social identity and the form in which stratification (asymmetry) conditions cultural practices. The chapter also examines the effects of asymmetry on scientific information consumption and cultural participation (visits to museums, aquariums, zoos, etc.), based on surveys of public perception and by using structural equation modelling (SEM). Finally, it is highlighted the fact how asymmetry reflects inequality and the latter weakens democratic scientific-technological culture.

INTRODUCTION

The still-ongoing Coronavirus pandemic, the climate crisis on the horizon and the unstoppable advance in artificial intelligence do nothing more than update the crucial importance of the scientific and technological culture. This is particularly true when forces are deployed in the area of an unsustainable industrial production model, and political messianism, xenophobia and racism, as well as the geopolitical wars for dominance in high technology, are exacerbated, or when we are faced with the consequences of rampant capitalism that produces global inequality and that, in addition, progressively instrumentalises all areas of social and individual life. The scientific-technological culture is a matter of cognition; that is, we require the best possible validated knowledge in order to understand the technological society and to operate in it in a competent manner.

The generation of enriched mental frameworks (perceptions and opinions) on impacts, benefits, risks and controversies is another of the modalities of the scientific-technological culture that garners singular relevance in a complex and unequal world. In the axiological sphere, furthermore, there is room for the defence of techno-scientific ethics at the service of civic morals committed to democratic values. Some time ago Cortina & Martínez (1996) postulated that “it is impossible to build an authentically democratic society solely with technically and socially skilled individuals, because such a society has to be sustained on values for which the instrumental reason is blind, values such as autonomy and solidarity, that inevitably compose the rational consciousness of democratic institutions" (Cortina & Martínez, 1996, p. 178).

The panorama is completed with that dimension in which the science is practiced, because being interested, being informed, gaining knowledge, being willing to be involved and participate as a citizen are forms of practicing science that contribute to strengthening abilities and deciding on courses of action as the risk culture or STS citizenry demands (López Cerezo, 2018; López Cerezo & Laspra Pérez, 2019; Cámara Hurtado & López Cerezo, 2012). Yet we must not forget -as often happens- that the opportunities to practice science are not a universal property. Instead, they are asymmetrically distributed throughout the social spectrum. Praxeology and social asymmetry are the focus of this chapter. First, it reviews some of the outstanding contributions to the conceptualisation of the scientific culture, placing special emphasis on the praxeological dimension. Next, it poses the problem of social identity and the form in which stratification (asymmetry) conditions cultural practices. Once this is done, there are examined the effects of asymmetry on scientific information consumption and cultural participation (visits to museums, aquariums, zoos, etc.), based on surveys of public perception and through the use of structural equation modelling (SEM). In the last part, it is highlighted the fact that the asymmetry reflects inequality and that the latter weakens the democratic scientific-technological culture.

PRAXEOLOGY

The praxeological dimension is a constant in the conceptualisation of the scientific culture. It is present in the theoretical approaches focussed on individual abilities, willingness and behaviour (Miller, 2014, 2010, 1998; Raza & Singh, 2012; Quintanilla et al., 2011; López Cerezo & Cámara Hurtado, 2007; Shen, 1975). But it also forms part of other perspectives that revisit the collective or social dimension of the culture of science and technology (Bauer et al., 2019; Bauer & Shukla, 2012; Vogt, 2012; Godin, 2012; Roth & Lee, 2002; Godin & Gringas, 2000). This second form of approaching the scientific culture has in turn two modalities: on the one hand, that which is centred on the communities and, we could say, on the collective processes of production and validation of knowledge in line with the tradition of the STS studies and, for example, with the contributions of social epistemology (Goldman & Whitcomb, 2011; see also the chapter of De Cózar Escalante & Gómez Ferri in this book). On the other hand, that which links subjective dispositions with objective conditions in which the structures of science and technology are developed. In this approach, the scientific culture deals with the expression of all the modes through which individuals and society appropriate science and technology. Society's culture is that which is permeated with contents of science and technology, an issue that is expressed on the institutional level, in public communication, in power mechanisms, or in individual opinions. In this sense, understanding the scientific culture involves knowing how science and technology are situated and distributed in particular social contexts (Godin & Gringas, 2000).

The imposition of surveys as a study technique emphasises the analyses in terms of individuals, although in no case is the society the sum of individuals. This generates the importance of the conceptualisation of the scientific culture, and the methodological and technical strategies for its empirical approach reconcile both focusses in order to circumvent the pitfalls of the old and sterile debate of the individual versus the society, and agency versus structures, or of the micro level versus the macro. These distinctions have an analytical and methodological use insofar as they do not lose sight that the social universe has a double existence that is expressed in what Bourdieu and Wacquant (1992) call the 'objectivity of the first order', constituted by the distribution of material resources and means of appropriating socially scarce goods and values, as well as in the 'objectivity of the second order', under the form of classification systems, mental and corporal schemes that function as symbolic models for practical activities, that is, behaviours, thoughts, feelings and value judgements of the social agents.

The practical dimension was already present in the first formulations of the concept of civic scientific literacy proposed and reworked by Miller (1983) over approximately forty years. Almond's (1950) influence offered him the appropriate framework of the civic (political) component, while Shen (1975) permitted him to underscore cognition, still predominant, although aided by provisions such as interest and informative practices. Thus, civic literacy would include knowledge of the basic constructs of science (scientific vocabulary and understanding of scientific news published in the media), comprehension of the methodology and dynamics of science, and the ability to recognise the social impacts of research and technological development (Miller, 1998). Information gained an even more relevant role in the most recent proposals of the author, as part of a reflection on the new modalities of acquiring information of current societies derived from the impact of digitalisation. It deals with the emergence of new information search and acquisition patterns that is called the 'just-in-time' model. Online navigation skills become, in this sense, increasingly relevant (Miller, 2014)[15].

In the approach by Cámara Hurtado and López Cerezo (2012), the image of the scientific culture is a stairway as a graphic expression of the relationship between the scientific culture and its behavioural dimensions, including the inclination to action in experiences of participation. In accordance with these authors, the levels (steps) reflect a certain gradual ordering of significant assimilation or scientific enculturation and not a genetic process of individual development, due to the multiple interaction among them: interest influences consumption, the latter influences the attributed importance, which in turn increases interest, etc. At the same time, this contributes to the inclination to use knowledge (both in ordinary and extraordinary situations of daily life) and to show a certain willingness to participate. The perceptual dimensions are not lacking in the process since the stairway also involves an evaluative consciousness of the potential effects of scientific-technological development.

Practice also constitutes a basic dimension in the approach that Bauer et al. (2019, 2012) make in examining the image, perception and cultural authority of science. According to these scholars, authority is presented in different ways, among others; paying attention means producing science news and showing interest and embodying science means giving mind space and attention to its topics. Yet it also means holding images and approaching science on various opportunities; endorsing science means to evaluate and to worry about its performance, and these relations to science are vested in knowledge and imagination (Bauer et al., 2019:17). In this way, the frame of reference of science culture is revealed by the correlational patterns among indicators of cognition,

15 A synthesis on the genesis and later development of the concept of scientific literacy can be found in Laspra (2018).

evaluation and behaviour. Furthermore, these patterns offer the key to the cultural authority of science in different parts of the world (Bauer et al., 2019, p. 19). To study it empirically, they propose the PREK model, which implements measurements related to promise (P), reserve (R), engagement (E) and knowledge (K).

The praxeological dimension is also included in the conceptualisation of the PIKA model (Perception, Interest, Knowledge and Action) developed during recent years by Muñoz van den Eynde (2018, 2014a, 2014b). The starting point of the model is that an image (a product of perception) is a complex mental map that people construct based on daily interaction with science. This map has the characteristics of a neuronal network of different nodes (the constructs or latent variables that the model studies) and their respective associations. In different analyses based on robust statistical methods such as those that structural equation modelling (SEM) provides, the author has obtained evidence that a segment of this neuronal network includes the relationships between knowledge, perception, interest, willingness to act, confidence and commitment to science (Muñoz van den Eynde et al., 2017, 2016; Rey Rocha et al., 2019). How society perceives science, its interest in the subject, how much it knows and what the actions are that it is willing to carry out allow deducing the existence of the scientific culture (Muñoz van den Eynde, 2014a).

IDENTITY

The review of the proposals on scientific culture in the specialised literature shows that it is a term in which three dimensions intercept. Following López Cerezo & Laspra Pérez (2018), they are the epistemic dimension (what we know), the axiological dimension (what we think) and the praxeological dimension (what we do). The epistemic dimension includes all the elements referring to scientific knowledge, the knowledge on research practices, on the system of science and technology, etc. The axiological dimension represents the general perception and attitudes, whether favourable or unfavourable, towards science and technology, as well as the evaluations of benefits and risks. The praxeological dimension is linked to actions (such as information consumption), behaviours and behavioural willingness.

With respect to the praxeological dimension, the theory is backed by empirical evidence. After several decades of surveys of social perception, the data confirm that interest, information consumption, capacity to become involved and cultural participation are closely associated factors (Polino & Muñoz van den Eynde, 2019; Bauer et al., 2019; Muñoz van den Eynde et al., 2017; Polino, 2018; Bauer et al., 2012; Polino & Castelfranchi, 2017, 2012). At the same time, they reveal that what we do (praxeology) can influence what we know (cognition) and what we value (axiology) about science and technology (Besley, 2019; Castelfranchi, 2019; Price & Peterson, 2016; Stares, 2012; Miller, 2012; Quintanilla et al., 2011; Miller et al., 1997). The problem is that the scientific culture models have delved rather little into the fact that what we know, think and do depends to a great extent on our social identity.

As individuals, we belong to social groups that define the limits within which we organise experiences, act and evaluate the world. In turn, we are subject to guidelines of social stratification that involve inequalities between groups and individuals in the society. The position that we occupy in the social structure determines the access to the goods, services or social rewards. With the aid of a sociological theory of the practice such as that offered by Bourdieu (1998), we could say that four forms of social capital exist which are relevant in understanding the social structure and the class position in highly differentiated societies: economic capital, linked to the possession of material goods such as property, wealth and income; cultural capital, in which are included education, artistic-cultural tastes, as well as leisure and consumption patterns; social capital, which expresses the networks of social relationships and personal contacts, more or less institutionalised, which lead to mutual knowledge and recognition; and symbolic capital, which rests on the idea of social reputation (and, in some respect, is similar to the idea of status in Max Weber).[16] Just as the social category tends to change slowly, other principles of stratification such as gender, age groups, migrant condition, ethnic or cultural minorities or religious beliefs are superimposed on them, which can be determining factors in specific circumstances and which, therefore, also impact the experiences and the opportunities that we have in life (Zajak & Haunss, 2020; Cuff et al., 2015; Grusky, 2014).

ASYMMETRY

Social identity is asymmetrical; therefore, we can expect that the praxeology of the scientific culture to also be asymmetrical. All the empirical evidence from the surveys points in that direction. For example, correlations and basic descriptive statistical analyses already serve to know that interest and information consumption increase with educational capital. But we could ask ourselves what reciprocal influence is exercised by different social stratification factors and what the dependent relationships are that would explain the interest or consumption in different cultural contexts. To respond to this type of questions, appropriate analytical methods are required that go beyond the correlations or linear regressions.

In this case, it is used the statistical techniques of structural equation modelling (SEM) which follow a confirmatory focus to study a structural theory on a phenomenon (Ullman & Bentler, 2013). The SEM approach has advantages over the traditional linear regression methods. While the bivariate correlation is not sufficient for examining prediction when using multiple variables in a regression equation, equation modelling permits relations amongst multiple variables to be modelled and statistically tested (Schumacker & Lomax, 2016, p. 6). Another advantage is that they permit incorporating in the analyses observed variables and latent variables (non-observable concepts), permitting an improvement in the statistical estimates, with their corresponding terms of measurement error (Byrne, 2016).

More specifically, there are used path analyses, one of the basic and oldest modalities of SEM (Kline, 2016). It allows studying the effects of exogenous variables (antecedents) and control (or intervening) variables on one or more resulting (or outcome) variables. In the diagram of a path

16 Weber began with the analysis of the social classes drawn up by Marx but modified and enriched it by offering a theory of a more elaborate and multidimensional stratification. According to Weber, the stratification in the modern industrial society is expressed in three dimensions: the objective economic inequalities derived from the "social class" -the only relevant factor for Marx; the status, which defines the social recognition through having an occupation or position, or following a certain lifestyle; and the party, linked to the political influence, that is, with power expressed as the capacity of the individuals or groups to impose their will.

model, the influence flows from left to right, reflecting the logical or chronological order of the model's variables. For example, the educational level of the persons can be influenced by their age, socioeconomic level or by both predictors (Figure 4).

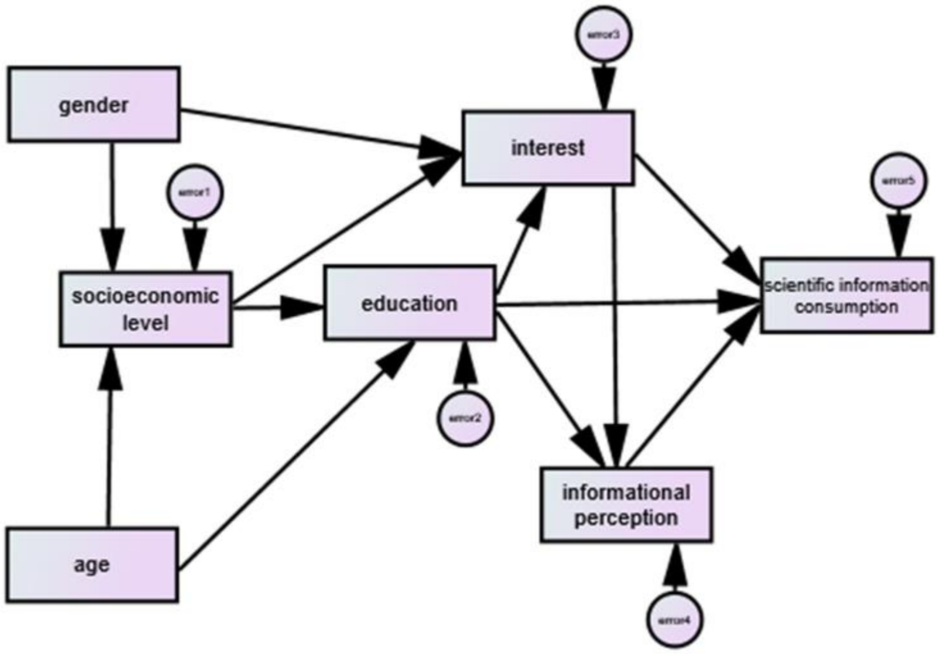

Figure 4. Path model to predict scientific information consumption. Example of a basic theoretical model

Whenever there is a statistically significant relationship between two variables of the model, they will be connected by an arrow that reflects the direction of influence. Each arrow is associated with a coefficient that goes from -1.0 to +1.0, a measurement of the relative strength of that relationship. The absence of an arrow means that the relationship between the variables is not statistically significant at the 0.05 level. The overall effects are composed of direct and indirect effects. The first imply that there is a direct path (indicated by the arrow) between any exogenous or control variable and the outcome variables. For example, in our model, that which links interest and scientific information consumption. Meanwhile the indirect effects are produced when the control variables explain all or part of the relationship between the exogenous variables and those of the outcome. For example, the influence that education exercises on interest and, through the latter, on consumption (Figure 4).

In this exercise, the objective is to determine the predictors of scientific information consumption and that which I call cultural participation. To do this, in this chapter are used the data from the science perception surveys applied to representative samples of the adult population of Argentina (2015), Brazil (2015), Chile (2015) and Spain (2016), which can give us an idea on the praxeology in different contexts. The consumption variable is an index that unites six questionnaire items on the use of television, newspapers, radio, science magazines, popular science books, and the Internet as information sources.[17] The cultural participation variable is another index that includes the responses to four items on the questionnaire regarding visits to science museums, art museums, zoos or aquariums and natural or environmental parks.[18] Interest is measured with another index with four items of the questionnaire, such as stating being interested in subjects of science and technology, medicine and health, food and consumption, and the environment and ecology. Another four items construct the index of informative perception, that is, that which reflects the question on how much the persons are informed on the same subjects over those that are consulted about the level of interest.[19] The models are completed with the variables of gender, age, educational level, and socioeconomic level (SEL), the last two as measured in the corresponding surveys of each country.

In the path analyses (one per country) in order to predict the information consumption (explained variable), we start with gender, age and territory (exogenous variables), through the measurement of the socioeconomic level (SEL), education, informative perception and cultural participation (control variables). We used the same structure for the cultural participation models, except in this case consumption is included as a control variable, while participation is the explained variable. For the effects of evaluating the quality of the estimates, the goodness of fit statistics show that the models are good; expressed in another way, the obtained data support the proposed model.[20] On the other hand, in accordance with the estimates of squared multiple correlations, the predictors have a greater capacity to explain consumption than cultural participation, while they also indicate that there are other surely important predictors that are not included in the models (Table 3 and Table 4)[21]

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17 The items make up the information consumption index (ICIC index) commonly used in Latin American studies. Polino & Castelfranchi (2017) evaluate the statistical consistency of the index as an indicator of the social perception of science. A compilation of its use with different technical procedures such as correlation matrices, factor analysis, cluster analysis, correspondence analysis, regression models, or structural equation models, shows that it is a consistent and stable indicator and, in this sense, relevant for international comparison.

18 The four items build up the cultural participation index elaborated in Polino (2018) to study the effects of social stratification on cultural practices based on survey data from a group of Latin American countries (Argentina, Brazil, Chile, Spain, and Panama).

19 All the indices are summation measurements of the items that compose them. In each case, and in the four countries, we validated them by confirmatory factor analysis (CFA).

20 The goodness of fit indices included in the final segment of Table 1 and 2 are statistics currently used in SEM techniques (Schumacker & Lomax, 2016). The division of the chi-square statistic by the degrees of freedom offers a measurement of global fit. Although there is no clear consensus, it is considered that a value between 1 and 3 means a correct fit. However, given that chi-square is a measurement that tends to increase with the size of the sample (as in the surveys of Chile and Spain), additional measurements are also used, such as RMSEA (Root Mean Square Error of Approximation) and CFI (Comparative Fit Index). The values of RMSEA below .05 are indicative of a good fit, while the CFI values must be over .90. It is also necessary to consider the parsimony of the model as done by the PCFI (Parsimony Comparative Fit Index) statistic whose values must not be below .50 (Byrnes, 2016).

21 There are at least three plausible explanations in this respect. First, both explained variables are aggregated indices. It is possible, therefore, that the joint treatment conceals differences that could be discovered if we obtained path models for each item treated individually, given the differences that there are, for example, between watching television and reading a popular science book; or else between visiting a science museum and going to a natural park. Second, there are specific variables of the surveys of each country that could have been incorporated as predictors increasing the explanatory capacity of the models. For example, the occupation could be a predictor of cultural participation or the political orientation and religious beliefs of scientific information. However, in this case, we opt to use a common core of strictly comparable predictors. The possibility, however, remains open for later work. Third, it is reasonable to think that there exist other significant social variables that the perception surveys do not include directly as questionnaire items and that, therefore, we do not know what effects they could exercise on consumption or participation. For instance, in the axiological dimension of the scientific culture, there are indications that lead to supposing that the values (political, moral, social), such as those that the World Values Survey (WVS) studies, could have a significant role in relation to some aspects of techno-science or specific applications of technology. However, the perception surveys scarcely include variables of this type. The tension between the study topics and the length of the questionnaire explains it to a large extent.

PREDICTORS	ARGENTINA (2015)	BRASIL (2015)	CHILE (2016)	SPAIN (2016)
Gender	0.08	0.00	0.00	0.00
Age	-0.04	-0.14	-0.13	-0.08
Territory	0.02	0.02	0.06	0.02
Socioeconomic Level (SEL)	0.21	0.07	0.18	0.08
Education	0.25	0.36	0.17	0.22
Interest (index)	0.31	0.29	0.41	0.51
Information perception (index)	0.32	0.23	0.30	0.62
Cultural participation (index)	0.25	0.21	0.23	0.00
R^2	0.32	.28	0.32	.59
Chi-square	53.8	53.9	95.7	96.3
Degrees of freedom (df)	21,00	20,00	19,00	20,00
CFI	0.987	0.987	0.958	0.993
PCFI	0.576	0.548	0.505	0.552
RMSEA	0.028	0.029	0.041	0.024
Upper confidence limit (RMSEA) 90%	0.038	0.039	0.045	0.030
Number of cases	1,936	1,962	7,637	6,357

Table 3. Standardized total effects of selected variables on scientific information consumption (index)

As for outcomes, the first that we can say is that gender and territory are factors that do not affect the practice of scientific information consumption in any of the four countries. On the country level, in Argentina the most significant predictors are information perception (0.32) and interest (0.31). Although both are measured by the effects that education and SEL factors exercise which, in turn, are found on a second level of relevance from the viewpoint of the total effects (0.25 and 0.21, respectively). Along with these latter, cultural participation also carries out a significant function (0.25). In Brazil, education is the key factor of consumption (0.36), followed by interest (0.29) which, for its part, is affected by schooling and SEL. Information perception (0.23) and cultural participation (0.21) are located on a secondary level. However, unlike that which occurs in Argentina, age exercises a certain influence in Brazil (-0.14). The negative sign indicates that as it increases, the search for information decreases. Age is also a factor with certain weight in Chile (-0.13), following the same logic as in Brazil. Although in Chile, interest (0.41), measured by the effects of the SEL, education and territory, is the principal factor that explains consumption, followed by informative perception (0.30). A similar situation occurs in Spain: information perception (0.62) and interest (0.51), affected by schooling, are the factors that exercise most influence on scientific information consumption (Figure 4).

The path models of cultural participation show that the same factors have different weight. In this case, age -with the exception of Argentina- is a factor that becomes more important, especially in Spain (-0.31). In fact, in this country it is the principal predictor that explains participation and that, in addition, affects both the SEL and education, the second factor in order of importance (0.27). The negative sign indicates that cultural participation diminishes as the age of the person increases. Information consumption is the most highlighted variable in Argentina, Chile and, to a certain extent, in Brazil, but not in Spain, where this role -along with age- is exercised by education. The SEL is a predictor of importance in Argentina and in Chile, although not in Brazil where education is the most significant factor. Territory has certain influence both in Argentina and in Brazil, indicating that the probability of participating is higher in the large cities than in the towns of lower population; nonetheless, this situation does not occur in Spain or in Chile (Table 4).

PREDICTORS	ARGENTINA (2015)	BRASIL (2015)	CHILE (2016)	SPAIN (2016)
Gender	0.02	0.02	0.00	-0.04
Age	-0.04	-0.15	-0.23	-0.31
Territory	0.11	0.11	0.07	0.02
Socioeconomic Level (SEL)	0.22	-0.04	0.25	0.12
Education	0.21	0.26	0.19	0.27
Interest (index)	0.14	0.14	0.22	0.19
Information perception (index)	0.17	0.17	0.08	0.04
Information consumption (index)	0.30	0.22	0.27	0.08
R^2	0.20	0.17	0.24	0.21
Chi-square	52.8	36.1	97.1	107.4
Degrees of freedom (df)	21,00	19,00	17,00	20,00
CFI	0.987	0.993	0.970	0.992
PCFI	0.576	0.524	0.508	0.551
RMSEA	0.028	0.021	0.054	0.026
Upper confidence limit (RMSEA) 90%	0.038	0.032	0.059	0.031
Number of cases	1,936	1,962	7,637	6,357

Table 4. Standardized total effects of selected variables on cultural participation (index)

There are three aspects that we can highlight based on this structural analysis of the survey data from Argentina, Brazil, Chile and Spain. First, the importance of social stratification to understand the structure and dynamics of the praxeological dimension of the scientific culture. Information consumption or cultural participation do not depend only on the interest that people may have, or solely on the education they have achieved. Consuming or participating depends on the interaction and reciprocal influence of a network of factors that favour or limit the possibilities of the persons being involved. In general terms, consumption and participation increase with educational capital or with the economic and social position, while they decrease among older persons, with fewer social ties, or among the inhabitants of small towns. In other words, producing practical culture also means having objective conditions for being involved and acting in consequence. This is another way of seeing that “a single public” of science does not exist but rather there are many according to different factors of social differentiation. Thus, it results that consumption and cultural participation in relation to science and technology are subject to the same social conditioning factors that affect the rest of the practices of cultural appropriation.

In second place is the fact that the praxeological dimension has a variable structure according to the type of practice that we evaluate. In a first approach, we can say that information consumption and cultural participation share predictors. In both cases, education and the socioeconomic level exercise considerable influence. But, in a second reflection, we observe that there are predictors that are of a more determining factor, depending on the type of practice considered. Interest and informative perception are more relevant in explaining consumption than for understanding cultural participation, while age and territory can exert a much clearer influence for understanding the probabilities of cultural participation. This circumstance reflects the difference existing between carrying out a practice based on the search for information through the media (TV, newspapers, radio, Internet) and other cultural formats (books and journals) compared to other types of practices that involve travelling to different locations in the urban or rural environment (museums, zoos, aquariums, natural parks, etc.)

Third, in addition to being variable, praxeology is diverse because stratification is also shown as distances between socio-political and cultural contexts that impart a singular and specific configuration to the actions. There are predictors that have more importance in some countries, while other have a stronger and systematic influence in others. All of this evokes the situational character of the scientific culture. In line with the affirmation of Bauer et al., (2019), while the performance of science is global, science culture remains locally bound. Expressed in another way, just as societies are not homogeneous and do not relate to science and technology in the way, neither are they symmetrical with respect to information, interest, expectations or the possibilities of being involved. In the case of cultural participation, these data coincide with other indications that can mean that the unequal distribution of the territorial variables, both between countries and between different areas, regions or types of cities in the same country, make access difficult to goods and services of social or natural heritage, also considering that this situation can differ according to whether you are dealing with museums, natural parks or other environments (Polino, 2019, 2018). Furthermore, it is not solely a subject in which the demand for information or participation by the society can differ between countries or between regions within the countries, but rather it also deals with the fact that the informative and cultural offers, as well as the political policies of promotion, fulfil a fundamental role in the scientific culture actions, making the social dimension of the scientific culture clear.

INEQUALITY

Asymmetry is a manifestation of social inequality. Just like what happens in other manifestations of the society and the culture, we observe in the surveys that the appropriation conditions of symbolic goods of the scientific culture are distributed asymmetrically in the social structure. The praxeology of the scientific culture seems fuller in specific social groups formed by interested, attentive and informed persons, who are, therefore, capable of expressing competent opinions on problems and questions of collective interest. However, the social identity is relevant: the data are indicative of a more dynamic praxeology in those individuals and social groups with sufficient educational, socioeconomic or cultural capital.

We could, therefore, ask ourselves up to what point does the right to benefit oneself from the opportunities offered by a full scientific-technological culture not continue being the terrain of a social minority. The practical scientific culture becomes in this way a problem of social justice (Dawson, 2019). A consequence is that promoting interest in subjects of science and technology is not sufficient, because interest is not a universal property but rather a socially situated and unequally distributed factor. This circumstance is growing particularly in societies such as that of Latin Americans with serious problems of injustice and inequality, where the democratic institutions are not secure, the political system does not manage to tend fully the demands of the people, or where there exists little capacity to combat the effects of the concentration of wealth and the growing distance between the poor and the rich. But also in Spain, where economic and social inequality have reached historic records in recent years as a consequence of the pandemic and the socioeconomic crisis (Aspachs et al., 2020). If, on the other hand, we assume that in democracy, informed and critical citizens are needed, capable of understanding and discussing science and technology, as well as acting in their support (Quintanilla, 2019), the social inequality weakens the scientific-technological culture understood as a political culture. In a more general sense, inequality impedes for the building of a techno-scientific citizenry.

PRAXEOLOGIES IN REGULATORY SCIENCE - A CASE OF BENEFIT ASSESSMENT

Noemí Sanz Merino

This contribution offers a praxeological analysis of the expert benefits assessment of food which is implemented according to the European Health Claims Regulation. Concepts borrowed from the Science & Technology Studies and social epistemology, such as 'epistemic cultures' of Knorr-Cetina, 'epistemic policies' of Luján and Todt, and 'civic epistemologies' of Jasanoff, are used. The objective is to show how both epistemic and non-epistemic assumptions determine the operationalization of this case of regulatory science and how its resulting praxeological features determine a priori certain implications that transcend its practice. Finally, this contribution argues that the diversity in the implementation of health claim regulation demonstrates that the choice of a particular approach to assessing health claims is not an inevitable consequence of the available evidence, nor the uncertainties present, but a consequence of the epistemic culture which experts assume as their own and of how regulatory objectives are epistemically interpreted.

INTRODUCTION

A Health Claim (HC) is a claim included in the labelling of some foods of general use which affirms that the consumption of these products or of one of their components (whether natural or artificial) has a specific beneficial effect on human health. In most industrialised countries, the commercial use of these declarations is subject to regulation. In general, this means that certain public institutions must authorise or reject applications for their use based on expert assessment on the claims' scientific substantiation. In other words, the current regulations on health claims correspond to an example of regulatory policy based on evidence, which is obtained in practice from a kind of regulatory science, in this case an instance of benefits assessment.

In fulfilling its function, expert practice of this kind must correspond to certain assumptions and objectives present in the regulations and follow its own (at least epistemologically speaking). In addition, in its implementation, regulatory sciences assume and put into practice certain procedures, standards, agencies, etc. Given this fact, this study is assigned to the fields of social epistemology and science studies which are concerned with regulatory science in general (e.g., Jasanoff, 1995; Funtowicz & Ravetz, 2000) or to be precise, with the relationship between the epistemic and non-epistemic aspects involved in the procedures of expert evaluation concerning science or technology (e.g., Luján & Todt, 2002; Aven, 2016; Cranor, 2017; Cox, 2015; Shrader-Frechette, 2010; Douglas, 2009).

Studies have already been published which in this sense take as a case study the evaluation of health claims (e.g., Jukola, 2019; López Mas & Luján, 2021; Sanz Merino, 2022; Todt & Luján, 2021). This research is based on these together with related official regulatory texts and on other studies on the regulation of health claims in general and/or on the more or less technical aspects of their possible systems of assessment (and from different countries) (e.g., Domínguez Díaz et al., 2020; Shimizu, 2015; Bagchi, 2014; Hart et al., 2013; Boobis et al., 2013; Tijhuis et al., 2012; Lalor & Wall, 2011; Gilsenan, 2011). This analysis is however concerned with highlighting the effects directly associated with the theoretical-practical features of this case of regulatory science, in particular insofar as these may have social implications which go beyond the aims pursued by the HC regulation.

The general objective of this study is to perform a praxeological analysis of the type of expert assessment imposed on the European food market regarding health claims since the enactment of the regulation in 2006. On the one hand, are identified the main theoretical and practical components which, in general, are involved in regulatory science starting from the characterisation suggested by Jasanoff (1995) on this mode of knowledge production. On the other hand, these components are analysed with regard to the case of Europe, taking up concepts such as those of the 'policy cultures' of science and technology of Elzinga and Jamison (1995) and the 'epistemic cultures' of Knorr-Cetina (1999). In particular, with regard to this last type of cultures, the contribution takes a close look at the 'epistemic policy' (Luján & Todt, 2021) which guides the European HC assessment, while with regard to the first type it will concentrates on the possible 'civic epistemology' (Jasanoff, 2005) which derives from it. Finally, attention will be paid to certain consequences which these praxeological features imply or may determine. To be precise, it will be examined the limitation which the kind of expert evaluation practised in Europe appears to impose in terms of social dissemination of scientific information relevant to consumers' health and to the possible engagement of non-experts in the trajectory of this techno-scientific innovation in food·

PRAXEOLOGY IN REGULATORY SCIENCE

Regulatory Science (RS) is the mode of production of knowledge habitually developed by experts aimed to provide advice in rulemaking or in the making of specific political decisions. This type of practice has continued to increase since the mid-20th century, which is largely due to its usefulness when promoting, administering, and/or assessing the scientific and technological problems themselves.

According to Jasanoff (1995), the main general but distinctive features (i.e., with regard to academic science) of regulatory science practiced in contexts of governability can be described as follows. RS is usually carried out at or by means of governmental agencies (*institution*) and its *goal* is to obtain scientific information (true, reliable) which is relevant to political activities. Its *products* are studies or data analysis in the form of reports which are not publishable, at least in typically academic contexts. The *incentives* encouraging the obtaining of the former are not habitually scientific incentives (professional recognition, knowledge advancement or innovation in a field, etc.) but rather the need to comply with legal requirements that arise, for example, from the implementation of regulatory policies. Moreover, scientific regulatory practice tends to be subject to the *time-frames* normatively established by such regulations and/or those which have arisen as a result of political and social pressure. The *procedures* of RS may take various forms (audits, regulatory peer reviews, judicial reviews, etc.) but are always far from the formal or informal contexts of peer review which is characteristic of the scientific communities. Finally, in establishing its *standards*, although absence of fraud or misrepresentation is understood, they are based on the protocols or guidelines of the agencies considered competent, whether these correspond to those shaped by the regulation to which the RS is serving and/or to those traditionally considered as the most suitable within the disciplinary fields of reference.

Such general features of the regulatory science are the result of the very characteristics of the often complex matters to be regulated. When expert advisors propose or select the scientific methodologies or the standards of evidence which they consider relevant in their work, they must also consider, for example, the regulatory objectives or the social, environmental, or public health consequences of their objects of study or assessment, which are often matters affected by high scientific or technical uncertainty and/or by ethical questioning (Jasanoff, 1995, 2005; Douglas, 2009). It is indeed habitual for regulatory science to develop in or arise from 'postnormal' contexts (Funtowicz & Ravetz, 2000), i.e., those affected by scientific controversy and/or by social pressure, in which it is necessary to make urgent decisions, etc. In any case, the factors and values that govern RS practices are not or cannot be reducible to the epistemic and technical ones of the traditional disciplinary paradigms of the sciences involved. Therefore, in contrast to what tends to be expected or defended with regard to the science practised in academic contexts, the influence of some non-scientific aspects in the practice of RS is often presented as a legitimate fact and indeed appears to be inevitable.

Although the praxeological features of RS are the specific result of specific needs and circumstances (not only social but also technical and scientific), it is equally reasonable to think that they themselves may involve certain consequences, both epistemic and non-epistemic. Indeed, evidence-based policies use RS out of such interest: to obtain the effects which have been anticipated as regulatory or political objectives.

In this manner, in following up specific political goals, RS is presented as a means to achieve them. It is in this sense that instruments are generated by the establishing of policies. On the other hand, *politics* are also established by choosing certain means. What is more, each case of RS has its own internal aims and, in order to achieve them, it also proposes or follows certain internal means and guidelines of its own. The objective of this study is precisely to analyse the possible implications of the designing and practising of a specific regulatory science. In other words, insofar as RS can be understood as a procedure or system for resolving problems, the theoretical-practical aspects which *a priori* may be determining effects or circumstances which go beyond it as techno-scientific practice will be emphasised.

In particular, it will be analysed in detail some of the features mentioned above which are characteristic of RS in the case of the regulation of health claims imposed on the member states of the European Union. This attention paid to the praxeology of this specific example and because of its possible effects is particularly interesting for several reasons. The European Union is an extensive transnational entity which also has considerable influence which goes beyond the international projection of public policies. Moreover, as we shall see in relation to this type of regulation, the EU attracts attention in particular owing to the highly demanding approach of RS imposed on the use of HC, for example insofar as the consequences of this approach appear to limit the very regulatory objectives and also go against certain other precepts of the European Commission on the governance of scientific/technological matters. This is in spite of its being a relatively recent regulation, in particular with regard to other jurisdictions which are equally outstanding in the international field. In the sections corresponding to analysis and discussion (five and six) this contribution will look more closely at what we mean by this.

THE CASE OF THE HEALTH CLAIMS REGULATION IN EUROPE

In 2006, the Regulation on Nutrition and Health Claims Made on Foods (European Parliament and Council, 2006) was established as part of a general European desire which would materialise with the Strategy on Nutrition, Overweight and Obesity-related Health Issues of 2007. It was however true that the regulation on HC not only sought to generate a society with healthier eating habits but corresponded likewise to another general interest of the time: increasing the economic competitiveness of European markets. The European Commission this began to intervene on a market which was already extensive, that of foods of general use which at the time were popularly known as 'functional foods'.

A Health Claim (HC) is a scientific declaration on the effect on health (either improving it or preventing a certain disease) of a natural or artificial food substance. The European HC regulation established that these declarations on food labelling (e.g., as an advertising ploy) must only be made if they are based on sufficient scientific evidence. The European Food Safety Authority (EFSA) became the advisory body which should assess the quality of the justification of claims to this effect, i.e., based on the scientific data provided by the applicants for use of a certain HC on the labelling on their products.

This ruling also stated that the experts of the EFSA should give their judgments on the substantiation of the proposed claims based on 'generally accepted scientific evidence' as that of the highest standard (European Parliament and Council, 2006). The reasons which were put forward to do so were the need to protect the consumer and to encourage a fair market for this type of food innovation (European Parliament and Council, 2006). It was assumed that the uncontrolled commercial availability of health claims involved dishonest market practice and increased consumer mistrust with regard to the public institutions and even science, apart from a possible risk to health (European Food Safety Authority, 2016).

In addition to scientific substantiation, the EFSA also had to assess whether the claim itself, together with the instructions for the consumption of the product (which must be attached so that the benefit of the food can be optimised or so that it does not harm the consumer) can be understood unequivocally by the average consumer. The Regulation of 2006 considered that both requirements were essential in that based on the assumption that in order to attain the objective of generating a society with healthier eating habits, the consumer must be well informed and sure as to which foods contribute towards improving his/her health (European Parliament and Council, 2006; see also European Parliament and Council, 2011).

In this way, while the EFSA became the body responsible for issuing this kind of benefits assessment of food, the regulatory authorities (in this case the Commission together with representatives of the member states) would approve or reject the use of the health claims proposed based exclusively on the report of said agency.

The regulation of 2006 remains in force and the EFSA continues today to act as the only assessment body authorised in this respect. Likewise, and as the authorities have been explaining, it continues to be the case that they do not interfere with the work of the experts except to ensure that the latter carry it out to highly rigorous scientific standards (see e.g., Directorate-General for Health and Consumers, 2011).

However, as will be discussed later by way of comparison, other important jurisdictions concerned with the use of HC have modified many of these normative aspects since their respective regulations were implemented. This has occurred, for example, with regard to the first to appear historically, the original US regulation of 1990 and the Japanese regulation of 1991.

EUROPEAN ASSESSMENT OF HEALTH CLAIMS

In accordance with the general incentive of suitably advising the authorities so that they can decide whether to authorise the HC requested, EFSA assumed the Commission's instruction to demand the highest scientific substantiation, that is, to just consider the evidence obtained according to the highest standard in accordance with what is generally accepted by the scientific community. On doing so, the experts of the EFSA turned epistemically this into stablishing as a requirement to be complied with by the HC applicants that the justification of the claims had to be based on studies establishing a cause-effect relationship between the substance and the benefit. In other words, despite being able to contribute another type of non-clinical studies as part of the scientific substantiation, the submitting of data obtained from Randomised Control Trials (RCT) on humans is a necessary condition if a positive assessment is to be obtained (European Food Safety Authority, 2016).

However, the providing of this type of substantiation is not sufficient for the assessment to be approved, as two further conditions must also be complied with (European Parliament and Council, 2006; see Article 16). On the one hand, the claims must be drawn up in such a way that it is made clear that they concern a specific benefit for a sector of the population (more or less extensive) which is likewise clearly defined. On the other hand, once it has been ascertained that the relationship is clearly defined and that it is sufficiently substantiated, the EFSA will assess whether the HC is understandable to the average consumer.

In order to measure the last of this sine *qua non* requirements, the Regulation imposed as a criterion that established by Council Directive 84/450/EEC of 1984 on misleading advertising, taking explicitly its concept of 'the average consumer': 'who is reasonably well-informed and reasonably observant and circumspect, considering social, cultural and linguistic factors' (European Parliament and Council, 2006, p.12). It will be the national courts and authorities which 'will have to exercise their own faculty of judgment, having regard to the case-law of the Court of Justice, to determine the typical reaction of the average consumer in a given case' (*Ibid.*).

Despite the fact that the application procedure is initiated by means of the administratively competent authorities of the member state to which the HC applicants belong, the totality of the assessment procedure is reduced to regulatory peer reviews carried out by the experts making up the EFSA Panel on Dietetic products, Nutrition and Allergies. The resultant reports of the assessments on each specific HC (both positive and negative) are published in the *EFSA Journal*; decisions of rejection based on them may be appealed against. A public list of all the HC assessed can be found on the European Register of Nutrition and Health Claims.[22] In principle, once an HC has been authorised it may be used by any food operator provided that on including it on the labelling of the products the latter maintains the same characteristics as those for which it was authorised in the first place. At present, around 260 HC have been authorised out of over 2300 applications which have been assessed.

CULTURES IN THE ASSESSMENT OF HEALTH CLAIMS

As far as techno-scientific practises is concerned one can speak of the existence of 'cultures' as collectives which arise and prosper at a certain time, and which can be differentiated precisely by the distinctive whole of their praxeological features. In the context of science and technology policies in general, the possible 'policy cultures of science' are representative of the specific interests of the series of actors involved in such political practices, but also and at the same time they are identified by certain wider preferences, such as politico-economical ideologies, ideals of science, and also with certain kinds of action and ways of relating to other groups, whether they are institutionalised or not (Elzinga & Jamison, 1995). If we follow techno-scientific practices in particular, 'epistemic cultures' can equally be identified. In other words, the activities which produce knowledge in each scientific field involve and/or are defined by technical and symbolic guidelines and structures, definitions, and manners in which epistemic strategies, empirical procedures, social collaborations, etc. are understood (Knorr-Cetina, 1999).

While different 'politics of science' can be distinguished in the first case as styles characterised by the way in which such cultures (for example political authorities, civil society, scientists, industry, etc.) are shaped to appropriate and use science to achieve different aims in specific political contexts (Elzinga & Jamison, 1995; see also Sanz Merino, 2008);[23] with regard to the second, and more

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22 Last access 30 sept 2021.

23 To be precise, it will be alluded to the possible establishing of civic epistemologies, i.e., as a type of politics of science in this sense, those which arise in relation to the governmental use of regulatory science (see below).

precisely in the context of regulatory scientific practices, their possible ‘epistemic policies’ can also be analysed. These represent the epistemological approach which dominates the choices of the scientific methodologies or criteria to be followed, it being the case that these are determined by factors or values which are not exclusively epistemic (Luján and Todt, 2021). Influenced by regulatory objectives among other factors, epistemic policies are representative of the epistemic assumptions by which evidentiary hierarchies, the burden of proof, treatment of uncertainties, etc., are imposed. In other words, they are those which in their turn and in our case determine the methodology of assessment or the requirements for the scientific substantiation of the health claims.

In the case of the European Union, the mentioned regulatory assumption (concerning the fact that the existence of false HC on the market may represent not only a risk to health but also undermine social confidence and harm private investment on this food innovation) became the assessment need to minimise the existence of false positives. In addition to this initial supposition of regulatory science itself, the experts of the EFSA also assumed the belief that the best way of achieving it was imposing proof of causality as a *sine qua non* requirement.

However, when the European Commission proposed to the EFSA that it should assess the substantiation of HC at the highest standard and its experts decided that this meant providing sufficient RCT studies on humans, it overlooked the fact that it is not currently *generally accepted* that this is the best kind of proof. There is at least significant disagreement between a large number of specialists in nutrition and the European assessment authorities on the fact that it is assumed that RCT are the most suitable methodology for generating data on nutrition science -see Todt & Luján (2017) for more details. According to the critics, the European authorities have accepted for this case a transfer of the practice of assessing the benefits of drugs to that of food without considering the respective particularities of their disciplinary traditions (Gregori & Gafare, 2012) (see Table 5).

While, in pharmaceutical testing, RCT are technically viable and tend to provide significant results, this type of studies is less usual in nutritional and bromatological R&D for several reasons. For example, nutritional research requires medium-term to long-term studies in which moreover the effects sought are slight. RCT are therefore a scientific methodology which is very difficult to apply with regard to foods in this sense but also in others. It has been argued that it cannot study satisfactorily aspects which may be determinant in the benefits assessing of diets (Tijhuis et al., 2012; Blumberg et al., 2010; Heaney, 2008). In particular, control over the necessary interaction between the multiple foods present in the normal diets of the persons studied hinders the studies, which also has a negative effect on the discernment of the functionality of the substances studied. In contrast, it is these peculiarities which support the fact that epidemiological or mechanistic methodologies (including in vivo with animals or cell essays) are those habitually used in nutrition and bromatology and which therefore represent valid alternatives to controlled trials in relation to the benefits assessment of food (Biesalski et al., 2011).

EPISTEMIC DIFFERENCES	FOOD	DRUGS
Target population	Healthy population	Sick population
Type of substances studied	Substances with highly complex functions (multi-functionality of nutrients)	Substances with very narrow and specific effects
Expected effects	Slight or imperceptible	Visible
Control times	Medium-long term	Short-medium term
Variability	Food interaction in general	Possible interaction with other specific substances
Habitual methodological precedence	Mechanistic studies	Mechanistic studies

Table 5. Some differences of epistemic culture - Food vs Drugs. Source: own elaboration

In consequence, it can be said and, in the terms, chosen that, in general, the European HC assessment takes pharmacology's epistemic culture as a point of reference for the requirements imposed by substantiation rather than that which emerges from food R&D. It can also be said that, precisely, it is this assimilation of this epistemic culture which has allowed the choice of the EFSA owing to a monist epistemic policy which is moreover highly demanding. This is the culture according to which it can be supposed that it is the causal data which constitute the most significant evidentiary proof of those used in nutrition, but also, considering the EU regulatory suppositions and objectives mentioned above, according to which it can be proposed that just HC based on RCT are valid.

What seems to be clear is that such choices of epistemic culture and epistemological approach do not respond to scientific or technical requirements but rather, as we shall see in the following section, to a certain paternalistic attitude of the regulators and to how this has been epistemically interpreted through what moreover is presented as a highly technocratic system.

The fact that there exist HC regulations whose regulatory sciences are implemented according to different epistemic policies corroborates the fact that these are to a large extent determined by factors which are more cultural or not only epistemic. In general, such other jurisdictions reveal different praxeological characteristics from those of European ones, beginning not for nothing with the assuming of other regulatory suppositions and objectives.[24]

For example, the HC regulation of the United States, the first of this type, has evolved considerably since its initial proposal in 1990 (Food and Drug Administration, 1993) when the praxeology of its assessment system was virtually identical to that now current in Europe and was based on the same assumptions. However, the Food & Drugs Administration (FDA) has always been in charge of authorising HC and not only of the assessment. With regard to the specific subjects of our analysis, the FDA introduced in the regulation at least two important modifications over the years. As from 1997 it allowed other governmental agencies and scientific institutions to take charge of the

24 For a more detailed comparison of the specific features of the epistemic policies of the HC assessment systems in the USA, the EU, and Japan and their historical evolution, see Sanz Merino (2022).

assessment of HC (Food and Drug Administration, 1997). Moreover, nowadays and since 2003 it has also considered evidence obtained with other types of scientific methodologies as valid in HC substantiation (Food and Drug Administration, 2003, 2009). In other words, the US epistemic policy is no longer monist but now methodologically pluralistic which is more in accordance with the practices of nutrition science, although HC based on other studies differing from RCT are considered by the FDA to be reliable albeit inconclusive claims (i.e., in accordance with lower levels of evidence).

It should be emphasised that the evaluating process of the FDA is also now open to the participation of non-experts. Albeit as a merely consultative element, a ‘panel period’ has been set up during which any interested individuals or entities may provide information which they consider should be considered with a view to authorising each of the Health Claims applications.[25] Indeed, the whole of the North American assessment approach can be considered to be more consumer-centred (Sanz Merino, 2022). On the one hand, the evaluating interest in consumers' understanding HC has been accentuated, both on including the requirement that consumers must understand the implications for their health of the type of evidence which supports each HC and on contemplating this possibility based on empirical studies on perception and understanding. On the other hand, these new features are, at least partly,[26] the result of a new regulatory attitude according to which part of the prior FDA solely responsibility with regard to the assessment of HC is shared. Consumers ultimately are those who can decide on the type of evidence (whether more or less conclusive) which is reliable enough to purchase a product which claims to be beneficial to health. This is so because HC appear specifically qualified in a manner relating to the type of evidence on which they are based (see example in Table 6).

The United States administration appears to have abandoned its initial paternalism on now assuming that increasing food information related to health, giving consumers wider decision-making powers, implies encouraging consumers' informed choice, the producers' right to inform and, in consequence, maximising purchase options (the same new specific regulatory objectives which in 2003 were added to those of protecting the consumer and the market). The FDA has epistemically turned these new regulatory objectives into its own new assessment aim of tolerating false positives, albeit in a relative manner. RCT continue to be considered of the highest standard, but it is now recognised that there is also ‘credible but limited evidence’ which equally deserves to be disseminated. However, it is necessary to ensure that these qualifications are also socially understandable as such, i.e., that there is a significant difference in terms of the impact on health between ‘Health claims’ (first level) and ‘Qualified health claims’ (second, third, and fourth evidentiary levels).

25 See the public website (last access: May 2021)

26 This flexibility of the assessment system also corresponded to the need to clarify and facilitate the application system. In 1999, the United States Court of Appeals of the District of Columbia Circuit ruled in favour of a group of plaintiffs consisting of a company applying for a HC and certain groups of consumers, deciding that the HC regulation was detrimental to the First and Fourth Amendments to the Constitution (see United States Court of Appeals, 1999). However, the low number of applications for HC submitted during that period, and the implications of this in terms of opportunity cost for this food market, were also clear (Parker, 2003).

HEALTH CLAIMS–HC (EUROPE)	QUALIFIED HEALTH CLAIM–QHC* (US)	FOOD WITH FUNCTIONAL CLAIM–FFC** (JAPAN)
Alpha-linolenic acid (ALA) contributes to the maintenance of normal blood cholesterol levels	Scientific evidence suggests, but does not prove, that whole grains (three servings or 48 grams per day), as part of a low saturated fat, low cholesterol diet, may reduce the risk of diabetes mellitus type 2 (Not authorised in the EU)	This product contains lactic acid bacteria GR-1® (*Lactobacillus rhamnosus*) and RC-14® (*Lactobacillus reuteri*). It has been reported that lactic acid bacteria GR-1® and RC-14® have the functions of improving the vaginal environment and regulating the condition in the vagina (Not authorised in the EU or the US)

* 'QHC' may correspond to up to 3 evidential levels according to normatively recognised scientific significance (types from B to D), which have been added to the pre-existing 'HC' category (currently: A-type level).

** 'FFC' are equally a type of health claim together with the already contemplated Foods for Specific Health Use ('FOSHU') and 'Qualified FOSHU' (both equivalent to HC and QHC respectively). However, under the current HC system, both FOSHU categories still need to be assessed by the CAA and according to the original respective evidentiary criteria.

Table 6. Examples of some possible evidentiary types of HC authorised according to jurisdiction. (Sources: respective national HC registers)

For its part, the Japanese regulation, which is influential in other Asian and Pacific countries, began by imposing a monist epistemic policy which was even more demanding than that of the European and the initial US system. Its first law in this respect established the condition of substantiating HC in accordance with various methodologies (with RCT and certain mechanistic studies) (Shimizu, 2015). Over the years it also evolved in a similar way to that of USA (see Lalor & Wall, 2011; Kamioka et al., 2019), although the Consumer Affairs Agency (CAA) has always been maintained as the only body in charge of assessment, at least until 2015. Then, a system was imposed to allow the possibility of marketing products under the 'Food with Functional Claims' (FFC) category, a HC kind in its own rights but that does not need to be assessed by the CAA although it must be authorised by virtue of a notification system (Consumer Affairs Agency, 2015). According to the latter, food producers only have to inform the authorities of the claim which they will use and at the same time provide as scientific justification a kind of evidence which in contrast has not been accepted by the European or North American regulations or by the previous Japanese ones: that obtained by literary reviews on specific substances. This latest change in the Japanese regulation appears to be a response to the intensification of the emphasis of the national administration on increasing the production and consumption of these foods, but also to a general interest in deregulating the markets (Kamioka et al., 2019). The CAA will have turned this from an assessment point of view into a simplification of the authorisation procedure, at least with regard to this new type of HC, which also increased the involvement of other stakeholders in the process. But, although its new epistemic policy is also pluralist in common with that of North America, these praxeological changes appear to correspond to a more business-centred approach.

In short, despite the limited praxeological approach of European regulatory science on HC, if we consider the international context there is no scientific agreement or even regulatory agreement as to which should be the standard to be imposed by the benefits assessment of food. While in the European case the assessment decision has been made to include the culture of the benefits assessment of drugs, the assessment systems of the United States and Japan seem also to have recognised the epistemic culture of bromatological and nutrition studies. Consequently, European Union continues to follow a monist epistemic policy while the latter two countries follow a pluralist one.[27] In the following last section, it will be considered some of the possible implications of these distinctive praxeological features.

IMPLICATIONS OF THE EUROPEAN HC ASSESSMENT PRAXEOLOGY

Up to now we have analysed the features of the European HC assessment system and also alluded to other possible characteristics with regard to the same praxeological aspects by means of comparing them with North American and Japanese cases. We have seen how such praxeologies, although also the result of previous regulatory assumptions and objectives, are finally determined to a large extent by epistemic-cultural choices assumed by the experts themselves. It is these which appear to allow the possibilities of choice among the epistemic policies which finally guide the assessment and based on the latter the choices as to its specific purposes and the procedures to achieve them. To finish, it will be examined some of the implications or possible implications of these choices.

An initial implication which may be emphasised has to do with the establishing of the various civic epistemologies which are determined by these sets of praxeological features at a wider social level. In other words, and according to the concepts discussed at the beginning, it can be said that the practice of regulatory science (through its praxeological peculiarities) is representative of certain politics of science according to which the involved policy cultures (in our case consumers, the industry, experts, etc.) relate each other and act with respect to science (Jasanoff, 1995; Sanz Merino, 2008). In this sense and in the case concerning us, the praxeology of the regulatory sciences implies certain civic epistemologies: 'institutionalized practices by which members of a given society test and deploy knowledge claims used as basis for making collective choices' (Jasanoff, 2005, p. 255).

The regulation of the health claims imposed in the European Union will in principle be representative of the type of civic epistemology which Sheila Jasanoff calls 'consensus-seeking'. In this epistemological style the attention paid to the various social interests related to the matters to regulate is indirect; in other words, it is generally the experts and certain elites, which are supposedly representative of the remainder stakeholders, who are invited to participate in the deliberations or the decisions. The countries in which the knowledge base of public policies is generated in this manner would show, according to Jasanoff (2005), that the governments themselves but also citizens in general have great confidence in the expert systems and the institutions which protect them. This is so as long as there is no sign of social rejection or controversy, which would no doubt lead to a more communitarian or directly a 'contentious' civic epistemology (see below and Table 7).

27 Concerning the use of monism/pluralism, see also Osimani (2020).

CIVIC EPISTEMOLOGIES	(US) CONTENTIOUS	(US, JAPAN) COMMUNITARIAN	(EU) CONSENSUS-SEEKING
Styles of public knowledge-making	Pluralist, interest-based	Pluralist, service-based	Institution-based (Governmental expert Agency)
Public accountability (basis of trust)	Assumption of distrust; Legal	Assumptions of trust; Relational	Assumption of trust; Role-based
Demonstration (practices)	Sociotechnical experiments	Empirical science	Expert rationality
Objectivity (registers)	Formal, reasoned	Consultative, negotiated	Reasoned
Expertise (foundations)	Professional Skills, Experience	Institutional experience, Professional Skills	Technical Qualifications (institutionally embodied)

Table 7. Civic Epistemologies in HC Regulation (Source: adapted to this case from Jasanoff (2005, p. 259).

Although in the preliminary stages of the designing of the EU regulation, a work group was used made up of various social actors considered to be relevant (experts, the odd consumers' association, and above all industry operators), since it has been approved both the practice of the assessment and that of the regulation are based exclusively on the expert rationality of a single governmental agency. In fact, if we qualify the features mentioned by Jasanoff for this type of civic epistemology in this specific case, it can be said that both the theoretical assumptions and the implementation of the assessment correspond to an especially technocratic approach. On the one hand, full confidence is expressed in the expert system proposed. The regulators delegate all the responsibility of their final authorisations or rejections to the criteria and judgement of government experts. The system therefore starts from and maintains a double separation of roles. According to what we have said, it not only operates based on the traditional separation between the assessment and management of science and technology (see e.g., López Cerezo & Luján, 2000) but also allows no decision-making by consumers and industry, which are precisely the groups it wishes to protect.

Not only the European technocratic stance but particularly its high paternalist attitude can be appreciated clearly if we also remember how in a theoretically pre-established manner the regulation and the assessment conceive and assess the average consumer and his/her potential understanding of HC. On the one hand, the Regulation not only considers consumers passively as mere recipients of the benefits (it does the same with food producers) but also in a homogeneous and limited manner as possessing specific attitudes and knowledge (Sanz Merino, 2020). On the other hand, they pre-allocate specific interests both to consumers and the industry, in our case the desire to be protected from erroneous information on the benefits of foods (Todt & Luján, 2021).

But as we will remember below (on addressing the respective implications of the United States and Japanese regulations), the civic epistemology of this case of regulatory science in the European Union could be different. However, the chosen scientific-regulatory praxeology moves this regulation away from the explicit European discourse which, also at the beginning of the millennium, was given in favour of the establishing of more participative and bottom-up mechanisms for governing science and technology, including the very advisory systems within the public institutions (see e.g., European Commission, 2001, 2007).

Although throughout its subsequent evolution, the epistemic policy of the United States has been affected by what could be termed as a contentious-administrative phase (to use the words of Jasanoff) during the gestation of its current version, its civic epistemology is now nearer the communitarian civic epistemology. The current Japanese system also appears to be representative of this latter type. In other words, in the US, with the acceptance of the methodological pluralism mentioned, in principle this would mean the awareness of the mistrust of producers and consumers which would have arisen with regard to the traditional assessment model.[28] In general, however, the new North American guidelines of 2003 institutionalised the pluralism of interests and perspectives (including scientific ones) behind the benefits assessment of food and, furthermore, increased the possible assessment entities and opened consultation mechanisms for different stakeholders. To a certain extent, therefore, in the US what is considered recognised expertise has been extended (as it is based on different possible forms of experience), owing to which it can likewise be understood that the HC authorisation is today justified on a negotiated objectivity. On the other hand, the presumption of trust has once again come to the fore. But now this feature also alludes to that delegated by the federal agency to the consumers themselves, as it is they who are finally to assume the responsibility of consuming the products with HC which are *just* credible. In the case of Japan, such trust and accountability also apply to food producers, albeit even directly binding as part of the assessment system (at least for the FFC category).

Having said that, the chosen praxeology of a regulatory science has not only implications as to how the production of knowledge is distributed or the epistemic and social responsibilities are finally attributed, but also affects how this knowledge may be socially or politically disseminated and used. In this regard, the second and final implication that I wish to deal with has to do, precisely, with what and how of compliance with the objectives initially pursued by the HC regulation.

The specific objectives of the European HC regulation are the protection of consumers from erroneous information and the encouragement of this type of innovation by means of protecting the HC market. If this is complied with, on the one hand, the regulation will allow citizens to be certain that the food consumed really improves health if this is what is claimed. On the other hand, it discourages dishonest business practices, which, together with the social corroboration of the benefits of foods with HC, will generate a general trust in this market and stimulate production. In other words, these procedures will provide feedback for each other so as to help to achieve a healthier society, which politically is the ultimate expected goal of this regulation.

As has been mentioned, however, there are very few HC on the European market. What is more, the food producers do not find it profitable to apply for the authorisation of the use of Health Claims given the high risk of a negative assessment (Khedkar et al., 2017). This is not however the case in the US, where there are many authorised HC, at least in the case of qualified,[29] and also more investment in this kind of innovation (Martínez, 2010).[30] Neither of course does it occur in Japan,

28 As has been mentioned and as can be considered a tradition in the US with regard to contexts of scientific-technological regulation (2005), the controversy was resolved in the law courts (see again footnote 5).

29 Last access: September 2021

30 In the same study however, it is argued that it is not clear whether this increase corresponds solely to the relaxation of the North American assessment system or also to the recent social increase in improved health by means of better eating habits.

where the HC market showed a turnover of 8 billion dollars in only the first three years of the last new regulation; over 400 HCs were approved in the first year alone (Iwatani & Yamamoto, 2019).

The fewer products with HC there are the less dissemination of information relevant to consumer health. So, which social service can provide highly reliable information on the potential benefits of some foods if precisely this information is not reaching society? Some authors therefore wonder whether the strict methodological monism imposed by the European HC regulation is not paying a high price with regard to the potential benefits in terms of public health (Luján & Todt, 2019; Blumberg et al., 2010).

In contrast, the social scenario may be different if, for example, other specific regulatory objectives were added and/or the initial assumptions change. This is the case in the US, where the encouraging of free informed choice was added to empower consumers together with the respect for the *First amendment* under the assumption that increasing the available information maximises purchase options.

Epistemically, the respect for the methodological pluralism of the culture of nutrition science allows more trustworthy information to, socially, be available and play a more relevant role. On the other hand, it should be carefully considered whether the deregulating turn in Japan, which has increased the production and sale of products with HC, implies that too much unreliable information is reaching the market and whether this is harmful to health, as some authors are already maintaining (Kamioka et al., 2019).

In any case, according to what we have seen so far, theoretical assumptions and methodological decisions, among other praxeological factors chosen in and for a regulatory science, have certain social implications which may go beyond or even against that expected in first place by the authorities. In this respect, as we have been concluding, to a large extent these implications are the result of decisions which could have been made differently, in particular if we consider that in the case of the HC regulation, they appear to have had more to do with non-epistemic decisions on what it is desired to achieve politically and how the regulatory science used to achieve it should be and should operate.

Despite this, and as assessing which is the best or socially most desirable praxeological ensemble in this case is not an aim of this study, it may be pointed out to finish that no public debate has been opened on such alternatives or their respective implications within the framework of the gestation or implementation of any of the three regulations mentioned.

EPILOGUE

A Health Claim (HC) is a declaration which establishes a specific beneficial relationship between a food and a condition of human health. Given that this type of claims is said to be based on scientific information, in the countries in which their use on food labelling is regulated, an expert assessment procedure on the evidence which supports it must be passed. This study has analysed the case of the benefits assessment of food imposed by the European Regulation on Health Claims with respect to its typical praxeological features as such regulatory science.

This case study showed how regulatory science (RS) assumes ‘epistemic cultures’ linked to certain scientific practices and how this may permit the establishing of ‘epistemic policies’, i.e., those choices which set the norm as to the standards and methodologies to follow so as to comply with the expert assessment. Epistemic policies are the result of non-epistemic or not only epistemic considerations; sometimes the latter may even be subject to specialised discussion. As we have seen, this is the case with regard to the European RS here studied.

According to this, and together with its comparison with other different praxeologies taken from other countries (the United States and Japan) for the same regulation, we have seen that different scientific-regulatory practices may lead to different social implications, for example for the market and innovation, for public health, or in terms of the governance of public affairs, among other possible aspects. In this study we have stressed the *a priori* implication which arises from the imposition of certain ‘civic epistemologies’ (more or less participative styles of producing knowledge which is the basis of collective decisions) together with the implications as to the ways in which it is possible to comply with the regulatory objectives.

It has been concluded that the benefits assessment of food carried out within the context of the European HC regulation has assumed an epistemic culture more in keeping with pharmacological R&D than that representing bromatological and nutrition science, which has permitted an epistemic policy depending on a highly demanding methodological monism (through its requirement to substantiate HC by means of clinical studies). Together with other praxeological features analysed, this makes this regulatory science representative of a the ‘consensus-seeking’ type of civic epistemology, with importance technocratic nuances or at least far removed from the contemporary European promotion of a more participative science and technology governance. Finally, it has been argued how the excessive paternalism that emerges from this regulation, in particular because the high epistemic demand imposed by its assessment system, appears to limit the initial supposition of the regulation itself: the convenience of disseminating information which is valuable regarding the health of consumers in relation to certain foods of general use. All this is despite the fact, as we have seen concerning HC regulations, that both certain features and their implications need not be the case.

In summary, on the one hand, the praxeologies of a regulatory science may respond, to a large extent, to certain decisions, among various alternatives, which may even be debatable both epistemically and non-epistemically speaking. On the other hand, these may have important effects, both foreseeable and debateable, for example in terms of the fulfilment of the specific objectives to be achieved by the regulation or of coherence of the latter with respect to more general political styles and wishes. It can however be pointed out that, despite what we have seen in relation to our case study, no public debate has been opened or promoted on which alternatives would be socially more desirable from among the different seen HC jurisdictions.

FOOD SCIENTIFIC CULTURE. A FOOD NEOPHOBIA CASE STUDY

Montaña Cámara; Virginia Fernández-Ruiz; Laura Domínguez; Esther Cruz

Food neophobia is related to the distrust and/or rejection of eating novel or unknown foods. Neophobic behaviour could have negative health consequences since neophobic people tend to consume the same foods repeatedly, so they adopt less varied and balanced diets. The study described in this chapter indicates that during the COVID-19 pandemic, young Spanish women showed slightly lower levels of food neophobia than before the pandemic. This finding suggests that the pandemic has contributed to making young Spanish women more aware of what they consume and its relevance to achieving optimal health.

FOOD SCIENTIFIC CULTURE

Food is the most essential consumer commodity for human beings with the highest frequency of purchase and consumption and, therefore, the highest number of daily purchase decisions by consumers, directly impacting health. With this consideration, consumer knowledge on food safety should be an important part of scientific culture and should be included in studies of the social perception of science (Alonso et al., 2019).

Food safety and quality have been major instinctive concerns for humans since ancient times and the reason for creating different quality and safety standards that have been modified over time. The first food laws, together with the basic control systems that ensured compliance, were created in the second half of the 19th century. Since then, food safety institutions, organisations and professionals have shared the challenge of ensuring that the population and, ultimately, the individual acquire an adequate level of scientific culture (understood as scientific literacy) in this matter. It is not enough to ensure that the population is well informed about food safety issues; the ideal scenario is one in which consumers have a base of scientific culture that allows them to apply information related to food safety in their day-to-day lives and helps them make informed decisions about the food they eat.

Without the involvement of all stakeholders (including consumers), it is not possible to meet all food safety objectives. It is necessary to ensure that all food safety programmes and policies reach the consumer, who will assimilate and integrate them until changes in their beliefs and behaviours are achieved. The goal of food safety professionals is, therefore, to achieve a food safety culture rather than a food safety policy.

The definition of the concepts involved in social perception and scientific culture is relevant and equally problematic because, as indicated by some authors, specialised literature appeals to different, and even interchangeable, concepts when referring to this link between science and society. Furthermore, it is not always possible to find suitable translations for the different terminologies (Laspra, 2018; López Cerezo & Cámara Hurtado, 2009).

In order to study how food security could be integrated into scientific culture, it is vital to know the true degree of scientific literacy of the population, as well as to know if literacy policies and measures actually have an impact and influence on the individual and if it is capable of integrating all this information. A scientifically literate person is one who understands that society controls science and technology through the provision of resources and uses scientific concepts, procedures and values in daily decision-making. A person who recognises the limitations as well as the benefits of science and technology in improving human well-being; who knows the main concepts, hypotheses, and theories of science and is able to use them; who clearly differentiates between scientific evidence and personal opinion; who has a rich view of the world as a consequence of science education; and who is aware of reliable sources of scientific and technological information and uses these sources in the decision-making process (Sabariego del Castillo & Manzanares Gavilán, 2006).

Food security is a scientific field in which citizens play an important role and, therefore, should be seen as a part of the scientific literacy of a population, allowing people to acquire this functional literacy, this ability to make informed decisions. So scientific literacy, unlike science literacy, presupposes a certain degree of appropriation of science by people, i.e. the impact of the scientific information possessed or consumed in their decisions or in their daily life.

At the European Union level, the population's loss of confidence in European food security due to a series of food crises that occurred in the 1990s, such as the illegal use of clenbuterol in fattening cattle, the so-called “mad cow crisis”, or the presence of dioxins in eggs and chicken and pork meat. These issues led to the creation of the European Food Safety Authority (EFSA), in January 2002, as part of the development of the White Paper on Food Safety of the European Commission (CE, 2000). EFSA was created, through Regulation (EC) Nº 178/2002, as an independent source of scientific and technical advice on food and feed, with risk assessment and communication functions throughout the entire food chain.

The integration of food safety into scientific culture (understood as scientific literacy) is not just about having a well-informed population, but also a citizenry with a good scientific culture base to be able to apply this knowledge in their day-to-day life; to make informed decisions (Alonso et al., 2019). Frank Yiannas, author of the book ‘Food Safety Culture. Creating a Behaviour-Based Food Safety Management System’, considers that the clear objective of food safety professionals (governments, institutions, public health professionals, etc.) should be to achieve a culture of food safety and not only a policy of food security (Yiannas, 2010).

The study of the scientific literacy of the Spanish population regarding the labelling of food products shows that there is (1) a significant lack of knowledge about basic aspects related to food safety and (2) a worrying lack of understanding about the value and usefulness of the information offered to consumers. At this point, it is worth highlighting the significant challenge presented by institutions, organisations, and professionals in food safety to (1) interest the population in this matter, (2) transmit the information in a clear, simple, and easily understandable way, as well as to (3) gain the trust of consumers as reliable sources of information and consultation (Alonso et al., 2019).

Ultimately, a scientifically literate individual with relation to food issues could be defined as one who is capable of (1) applying scientific concepts, procedures, and values in their day-to-day lives and food purchasing and consumer decisions; (2) understanding and appreciating the great power that society can have in controlling science and technology with the help of resources, as well as the usefulness of science in improving human well-being; (3) recognising reliable sources of scientific and technological information and taking them into account in decision-making.

The interest of citizens in science, technology, food, and health exists, and institutions and governments are not alien to this, both at national (FECYT, 2021) and international level (EFSA, 2019).

The last Eurobarometer on Food Safety (EFSA, 2019) provides insights related to Europeans' overall interest in today's food issues, such as food safety, including factors affecting food-related decisions, eating habits and food choices. Results show that taste, with 49% among the general population and a higher percentage among young people, is one of the key factors for Europeans when buying food, especially in the Netherlands. Spain displays a lower rate (45%). Related to organoleptic traits, there is a great concern about additives like colouring, preservatives or flavourings used in food or drinks (72%), even higher among the Spanish population (75%). Socio-demographic analyses show that women are more interested in food safety (44%) when compared to men (38%).

Although food safety itself is not a study topic that will be included in the FECYT surveys, we do find information on related topics, such as medicine and health or food and consumption. The latest survey on the social perception of science carried out in Spain by the Foundation for the Study of Science and Technology (FECYT, 2021) shows that the issue that has aroused the most interest in the Spanish population has been the COVID-19 pandemic (46.2%), followed by labour concerns (27.4), food, and health issues (27.1%). If we ignore the circumstance of the pandemic, Spaniards indicate that they feel more interested in food and consumption issues rather than in the rest of the topics presented, with an average rating of 3.6 (1 being the minimum and 5 the maximum), only surpassed by medicine and health (3.79). Spontaneously declared interest in medicine and health amounts to 26.2% of the total number of people interviewed in Spain, while food and consumption account for 27.1%. This interest in food issues has significantly increased since the latest edition (FECYT, 2018), and it is higher in the female population than in the male population (3.74 and 3.44, respectively).

FOOD NEOPHOBIA AS PART OF THE FOOD SCIENTIFIC CULTURE

Food neophobia is defined as the "fear or rejection of new or unknown foods by the individual" (Pliner and Hobden, 1992); it is a personality trait that influences the choice and sensory acceptance of new foods (Capiola and Raudenbush, 2012). Food neophobia is related to the distrust and/or rejection of eating novel or unknown foods. This reluctance to try new or unfamiliar foods can occur for various reasons, including the taste, smell, texture, and appearance of a certain food, as well as its relationship with a previous negative experience. In addition, the level of food neophobia varies according to the individual and other factors such as age, sex, education and/or place of birth (Flight et al., 2003; Pliner, 1992; Tuorila et al., 2001).

In Europe, novel foods are considered foods or ingredients whose molecular structures have been modified or those obtained after major modifications through an unusual production process before 15 May 1997. In this essay, we consider Novel foods according to the Regulation (EU) № 2015/2283 but also all new foods that are obtained after undergoing significant modifications during the production process and/or those that are unknown or new to the individual who consumes them.

Previous studies have suggested that high levels of food neophobia have a profound impact on health (Domínguez et al., 2019). Neophobic behaviour could have negative health consequences since neophobic people tend to consume the same foods repeatedly, so they adopt less varied and balanced diets and, in general, they tend to consume less plant-based foods, such as fruits and vegetables.

Neophobic children tend to consume fewer fruits, vegetables, and fish. Others such as pasta, rice, and sweets, which affect the diversity and balance of their diet and result in a higher caloric intake (Maiz & Balluerka, 2016), replace these foods. As children grow and approach adolescence, their experiences with food are more varied and frequent; therefore, they tend to be less neophobic as they gain experience with new foods and develop other tastes (Andrade Previato et al., 2017; Dovey et al., 2008). In adolescence, food is mostly consumed for reasons of pleasure and/or reward; therefore, food choices mainly focus on palatable foods (for example, sweets and fats) that provide pleasure. In a study carried out on adolescents (Andrade Previato et al., 2017), it was observed that they had moderate levels of craving for sweets (69.7%), using food as a reward (67.4%) and for pleasure (73.5%). That pleasure was related to physical inactivity, a lack of interest in looking for the best nutritional option, and being overweight or obese. The more neophobic adolescents ate fewer fruits, vegetables, fish, and cereals or grains for breakfast. In addition, they skipped breakfast more frequently and consumed more sweets than the more neophilic adolescents (Maiz & Balluerka, 2016). According to the results of this study, the most neophobic adolescents followed a less balanced diet and a less healthy lifestyle since they tend to consume higher calorie foods such as sweets and perform less physical activity.

In the specific case of young adults, they are more reluctant to try unfamiliar foods. It has been shown that young adults tend to consume more processed foods (with a higher content of saturated fat, free sugars, and salt) and fewer foods that are rich in fibre, vitamins, minerals, and bioactive compounds mostly present in foods of plant origin (Andrade Previato et al., 2017; Domínguez et al., 2019; Ruiz Moreno et al., 2014).

A study conducted in adults between 19 and 49 years of age showed that participants rated the foods with which they were familiar with the highest scores (Raudenbush & Frank, 1999). The scores given to familiar foods did not present statistically significant differences between the individuals who were neophobic and the neophiliacs; however, differences were observed in the scores given to foods that were not familiar to them. Neophobic individuals scored these foods negatively. Therefore, it was concluded that neophobic individuals have different expectations about foods that they do not know compared to those that they do, and these expectations influenced them when trying these foods.

In a study carried out in Finland by Tuorila et al. (2001) on individuals aged between 16 and 80, it was observed that food neophobia decreased with age up to 65 years of age and then increased from 66 to 80 years of age. To date, the reasons why elderly individuals avoid certain foods are unknown. According to Dovey et al. (2008), this rejection may be due to their ignorance of these foods and to the belief that consuming them may cause some disorder, for example, gastric discomfort. If neophobia in older people is a response to a weakened state of health, then this form of food neophobia may be related to the perception of the state of health (including dental health). The stronger (in terms of health) they think elderly individuals are, the less food neophobia they will show and the more "risks" they will be able to take. In addition, among the elderly, there is a decrease in the senses and the ability to detect and differentiate the odours of food. However, data on food neophobia in the elderly are relatively scarce, and further studies are required (Dovey et al., 2008).

Regarding gender, women consume less food throughout the day and consume less alcoholic or sugary beverages and foods with a high caloric content (Maganto et al., 2016). These authors showed that the diet of women is significantly healthier than that of men by ingesting less unhealthy foods, such as fried foods, sweets, and precooked food, as well as alcoholic, energising and sugary drinks. The previous results regarding the level of food neophobia do not seem to differ with respect to gender; however, in situations of mood disturbances, women's diets can become unhealthy and result in extreme dietary restrictions, and risky nutritional errors.

Human beings have always tended to select the familiar over the novel to avoid potential risks linked to the unknown. Thus, the COVID-19 pandemic has come with major changes in every respect and has forced individuals to face up to unknown and stressful situations. This can be easily understood as there is an undeniable relationship between an adequate diet and good health, and we all know that correct eating habits can contribute to the prevention of diseases, quite critical issues in the current pandemic situation (Cámara et al., 2021). Fear and uncertainty have marked recent months, above all during global confinement, which has had a great impact on eating behaviours and patterns.

FOOD NEOPHOBIA CASE STUDY

As several studies suggest that high levels of food neophobia have a major negative impact on health, we want to study young adults ("millennials") among the female population of Spain, considered by authors as a population of great interest (Domínguez et al., 2021).

To evaluate the state of the art, first a review of the scientific literature published about food neophobia and its relationship with health was carried out using the scientific databases PubMed, Google Scholar, Science Direct. The following keywords were used: "Food Neophobia", "Food Neophobia Scale", "Health Impact", "Female Millennials". Secondly, a comparative analysis of the levels of food neophobia among 190 Spanish female millennials (18-35 years) pre and during the COVID-19 pandemic was performed (Figure 5). The sample consisted of 90 female from 18-35 years previous the COVID-19 pandemic, and 100 female on the same age interval during the pandemic. Sample sizes were 168 and 100 respectively.

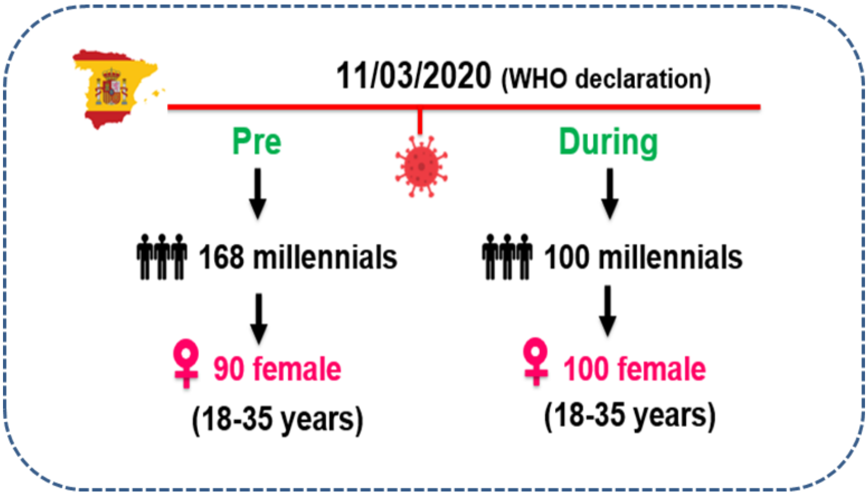

Figure 5. Design and sampling of the food neophobia case study (Domínguez et al., 2021).

Food neophobia levels were measured using the Spanish version of the Food Neophobia Scale (FNS). Participants responded in a self-applied way that evaluated their degree of neophobia using the adapted Spanish version of the FNS (Fernández-Ruiz et al., 2013). As shown in Table 8, the FNS is made up of 8 items valued on a seven-point Likert scale that ranges from "completely agree" to "completely disagree". It is important to highlight that there are positive and negative or reverse items. In the case of negative items (R), the average scores should be inverted in order to evaluate the level of food neophobia (Fernández-Ruiz et al., 2013).

ITEM	ENGLISH ITEMS	SPANISH ITEMS
Item 1	(R) I am constantly sampling new and different foods	(R) Estoy constantemente probando alimentos nuevos y diferentes
Item 2	I don't trust new foods	No confío en los alimentos nuevos
Item 3	If I don't know what a food is, I won't try it	Si no conozco qué hay en un alimento, no lo pruebo
Item 4	(R) I like foods from different cultures	(R) Me gustan las comidas de países diferentes
Item 5	At dinner parties, I will try new foods	(R) En las fiestas con comida, pruebo nuevos alimentos
Item 6	I am afraid to eat things I have never had before	Me da miedo probar alimentos que nunca he probado antes
Item 7	I am very particular about the foods I eat	Soy muy especial con los alimentos que como
Item 8	(R) I like to try ethnic restaurants	(R) Me gusta probar nuevos restaurantes étnicos

Table 8. Food Neophobia Scale (English version and adapted Spanish validated version used in the present study) (8 items) (Based on: Fernández-Ruiz et al., 2013). (R) means negative item.

To put this study in the context of the current pandemic situation, the respondents also answered some questions about food neophobia and COVID-19 in order to know the possible impact of this disease on the results obtained from the levels of food neophobia. Data have been analysed, and the mean and standard deviation of each item, as well as the mean and standard deviation of total scores, have been calculated, as shown in Table 9. The higher the score, the higher the levels of food neophobia.

	PRE PANDEMIC		DURING PANDEMIC	
ITEM	Mean[1]	S.D.	Mean[1]	S.D.
Item 1	2.79	1.43	3.53	1.62
Item 2	3.36	1.57	2.60	1.55
Item 3	4.13	1.82	3.44	1.83
Item 4	2.11	1.23	2.43	1.75
Item 5	2.48	1.28	2.38	1.43
Item 6	3.02	1.68	2.93	1.82
Item 7	4.77	1.71	3.37	2.09
Item 8	2.77	1.61	2.62	1.93
TOTAL	25.42	8.06	23.30	9.08

Table 9. Average scores of food neophobia pre and during the COVID-19 pandemic (N=190) (Domínguez et al., 2021).

In addition, to evaluate the reliability of the FNS, the internal consistency has been calculated using Cronbach's alpha, based on the average of the correlations between the items. The result obtained for Cronbach's alpha was 0.8, which means that the tool used has good consistency. Similar results to Cronbach's α (0.76 – 0.85) were found in other studies carried out on millennials of the same age group (18 – 36 years old) (Edwards et al., 2010; Ristic et al., 2016; Tuorila et al., 2001).

Confinement due to the COVID-19 pandemic caused modifications in the Spanish eating pattern, which may be due to people's greater awareness and interest in improving their health in the pandemic situation. The study conducted in Spain, on people over 18 years of age (Pérez-Rodrigo et al., 2020), showed that the fact of planning food, thinking about what to buy, and therefore getting involved in how to prepare and consume food, have made Spaniards more aware of what they eat and increased their consumption of fruits, vegetables, legumes and fish. This change has also reduced the consumption of products with a high content of free sugars, saturated fats, and salt (such as ultra-processed foods: industrial pastries, salty snacks...), which can help achieve a healthier diet.

As can be deduced from the information included in Table 2, Spanish female millennials during the COVID-19 pandemic (D) were less neophobic (23.30 ± 9.08) than in the pre-pandemic situation (P) (25.42 ± 8.06). This fact can be confirmed by the lower average values given to Items 2, 6 and 7 during the COVID-19 pandemic when compared to pre-pandemic values.

Female millennials were less selective with the food they ate during the pandemic (Item 7); however, there are no differences when it comes to trying ethnic food (Item 4) and when they are enjoying their leisure time, like at dinner parties (Item 5). Female millennials pre and during the pandemic want to try novel foods cautiously and want to know what foods contain before trying them (Item 3). This fact can be explained by the high degree of education of the participants, who, being aware of nutritional problems (allergies, intolerances) or their way of eating, may reject the intake of certain food groups, foods and/or ingredients for various reasons: religious, social, or environmental (responsible and sustainable eating) (Domínguez et al., 2021).

Statistical analysis between food neophobia levels in Spanish female millennials of both periods (P and D) were performed using Statgraphics Plus version 5.1. As shown in Figure 6, the comparison between medians reported statistically significant differences between both groups P and D (α = 0.05) using the Wilcoxon-Mann-Whitney test (Domínguez et al., 2021).

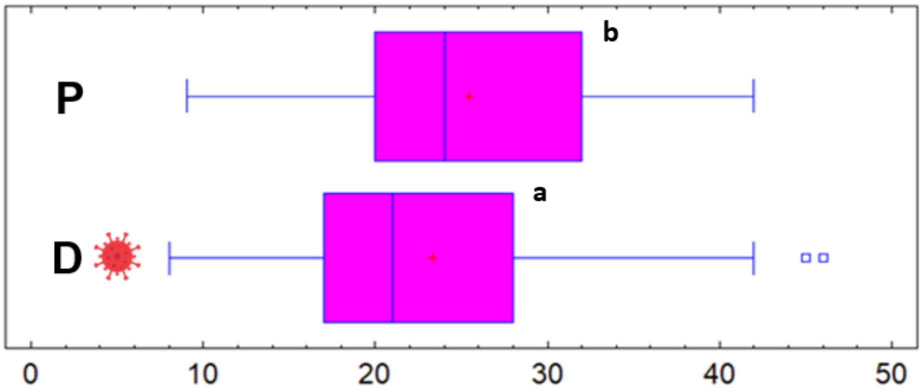

Figure 6 Comparison between medians of female millennials pre (P) and during (D) the COVID-19 pandemic (N=190).

Different letters mean statistically significant differences (α = 0.05).

Food neophobia scores obtained pre and during the COVID-19 pandemic were split into terciles ('low neophobia' (L), 'medium neophobia' (M) and 'high neophobia' (H)) based on approximately 33% membership in each group. Statistical differences between terciles (L, M, and H) in both periods (pre and during the COVID-19 pandemic) were found (α = 0.05) using the HSD Tukey Test. Only the medium neophobic tercile (M) showed significant differences pre and during pandemic (Figure 7) (Domínguez et al., 2021).

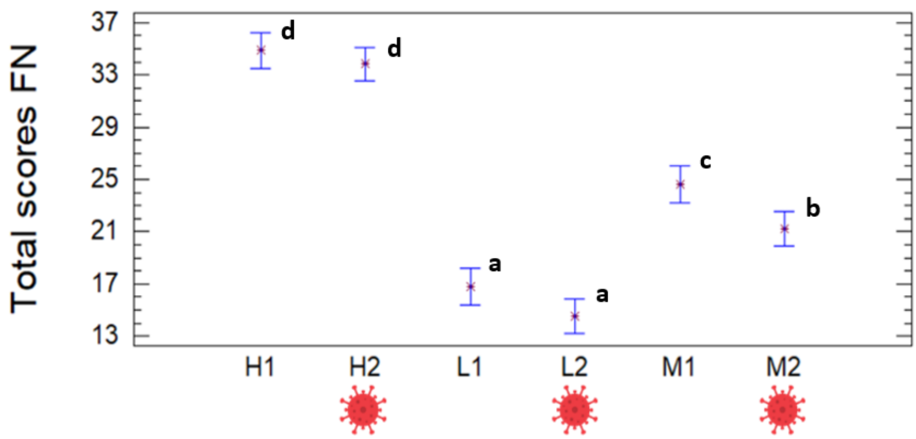

Figure 7. Comparison between food neophobia (FN) terciles (L, M, and H) of Spanish female participants. 1 = pre-pandemic; 2 = during the COVID-19 pandemic.

Different letters mean statistically significant differences (α = 0.05).

According to scientific literature, Spanish female millennials during the COVID-19 pandemic reported lower food neophobia results (23.30 ± 9.08) than other studies performed on young Spaniards before the pandemic (25.80 ± 7.75 and 31.74 ± 10.98) (Domínguez et al., 2019; Fernández-Ruiz et al., 2013). Likewise, female participants of the present study were less neophobic than millennials from America (36.7 ± 10.1), Australia (32.5), Asia and Europe (30.68 ± 17.36), Lebanon (30.1 ± 11.7), and Finland (32.3 ± 11.1) (Edwards et al., 2010; Olabi et al., 2009; Ristic et al., 2016; Tuorila et al., 2001).

Therefore, a decrease in food neophobia is observed during the pandemic caused by COVID-19. Spanish women between 18 and 30 years of age could be more aware of what they ate after the onset of the pandemic in order to achieve optimal health so that they would be in a better condition to deal with the infection if they were infected by COVID-19.

On the other hand, other questions included in the survey used in the present study revealed interesting results. Spanish female millennials were asked whether they had experienced changes in their usual diet during the COVID-19 pandemic. The majority of respondents answered no (67%), stating that their level of food neophobia had not increased (98%). Interest and motivation when trying new foods during the pandemic increased in 42% of the participants, while 52% had not experienced any change. Specifically, when asked about the consumption of alcoholic beverages, the majority (76%) expressed that they had not experienced any change in their consumption pattern during the COVID-19 pandemic (Díaz et al., 2021).

EPILOGUE

The integration of food safety in scientific culture by the general population will result in a modification of eating and purchasing habits allowing citizens to apply this knowledge to make informed health improvement decisions.

Nowadays, citizens display great interest in science, technology, food, and health, as seen at national (FECYT, 2021) and international levels (EFSA, 2019). In fact, the last Eurobarometer on Food Safety (EFSA, 2019) provides key information related to Europeans' overall interest in today's food issues, such as food safety, including factors affecting food-related decisions, eating habits and food choices. As a consequence, institutions, organisations, and professionals in food safety have great challenges, such as (1) interesting the population in this matter, (2) transmitting the information in a clear, simple, and easily understandable way, as well as (3) gaining the trust of consumers as reliable sources of information and consultation.

Food neophobia has a major impact on the food choices and eating habits of the population and is associated with serious public health problems. It is considered a significant limitation for adopting and following a healthy, varied, and balanced diet. The most neophobic individuals tend to follow unbalanced diets derived from the rejection of some types of food. Therefore, knowledge about the level of food neophobia using the FNS scale and its consequences should be taken into account since it can be used as a tool to help optimise the diets and, therefore, the health of individuals.

Young adults are more reluctant than adults to try new foods, although their levels of food neophobia tend to decrease with age. Understanding food neophobia in this group is very important, as their eating habits are generally considered less healthy. The results of the present study using the adapted Spanish version of FNS indicate that this interviewed group of young Spanish women are less neophobic (23.30 ± 9.08) than millennials from America (36.7 ± 10.1), Australia (32.5), Asia and Europe (30.68 ± 17.36), Lebanon (30.1 ± 11.7), and Finland, according to the scientific literature. When delving into the interpretation of the FNS items, it should be noted that items 1 ("I am constantly trying new and different foods") and 3 ("If I don't know what's in a food, I don't try it") obtained the highest average scores. These data could reflect that this group of young women want to try new foods (high value of item 1) but cautiously (high value of item 3), i.e. they want to know what the food contains to try it. This fact can be explained by the high degree of education of the respondents who, being aware of problems such as allergies, intolerances or even consistency with their way of eating, may reject the intake of certain food groups or ingredients for religious, social, or even environmental concerns related in some way to a responsible and sustainable diet.

This study shows that the degree of food neophobia of young Spanish women during the pandemic caused by COVID-19 is slightly lower than that shown by young Spanish people before the pandemic ($\alpha = 0.05$). This fact might suggest that young Spanish women are more aware of what they consume after the pandemic in order to achieve optimal health and to be in a better condition to deal with the infection if they were infected by COVID-19. These differences were statistically significant in the medium food neophobic tercile (M) of Spanish female participants pre and during the COVID-19 pandemic.

ARE SCIENCE ACTION AND TECHNOLOGY FLOWS COMPATIBLE WITH THE DISCOURSE FOR ACTION AGAINST CLIMATE CHANGE?

Jesús Rey Rocha; Victor Ladero; Emilio Muñoz

Climate change is one of the greatest challenges facing humanity. The consequences for the entire planet of its effects are so serious that we cannot remain impassive. Yet there are a wide variety of economic, social and political obstacles to be faced to reducing greenhouse gas emissions, denialists in all groups being of particular concern. In the broadest meaning of the term, science must develop a determinant role in climate change fight leadership. Research data supporting evidence of climate change must be accompanied by speeches addressed to society, politicians and businesses with the aim of leading a common response to achieve the ultimate goal. This chapter's reflections are built around examples of scientific and technical communication on climate change. It concludes focusing on the particularities of the Spanish situation to highlight the importance of taking into consideration cooperation and altruism, and values such as responsibility, trust, empathy and social justice.

REFLECTIONS AROUND CLIMATE SCIENCE SOCIOLOGY AND POLITICS

CLIMATE CHANGE: EFFECTS AND HOW TO COMBAT IT

Climate change is a long-term change in the average weather patterns that define Earth's local, regional and global climates[31]. Although the climate is continuously changing, not two days from different years have the same weather, the term became popular in the 1980s to refer to the effect of greenhouse gases on the climate and, more specifically, on global warming. Other terms, such as climate crisis or climate emergency, have been used as synonymous by different scientists or politicians to emphasise the concern and severity of the problem.

In the earth's history, there have been various periods -that span several thousands of years- of climatic change -ice ages alternating with warming periods- that were influenced by several factors, such as changes in the earth's atmosphere, the position of the continents, fluctuations in ocean currents, variations in the earth's orbit and the sun's energy output. However, in recent years, a rapid -from a geological time span- increment in the global temperature (Global warming) has been observed by scientists all over the globe (IPCC, 2013). Since the mid-20th century, humans have had an unprecedented impact on Earth's climate system that has caused changes at a global scale. The

31 A complete definition and more information can be found at: Climate change. (23 September 2021) In Wikipedia

term *Climate change* refers to the resulting large-scale shifts in weather patterns observed, including *global warming*, driven by human-induced emissions of greenhouse gases -mainly carbon dioxide (CO_2) but also methane, ozone, nitrous oxide and chlorofluorocarbons (CFCs)- originated from industrial activities and fossil fuel production and combustion (Center for Climate and Energy Solutions, 2021).

EVIDENCE FOR CLIMATE CHANGE

A large number of variations and anomalies in climate series have been observed since the mid-20th century. Although there is a lack of direct records in previous years, there are some historical data recorded -floods, frost, hail storms- that together with geological -erosion and deposition of materials- and biological -plant growth, distribution of species- analysis allowed for the observation of a rise in global temperature. This warming effect has been accompanied by several climate alterations that affect oceans, ice and global and local weather.

Climate data records provide evidence of climate change key indicators, such as Earth´s surface and ocean temperature increases; ice reduction at both Earth's poles and glacial and permafrost thawing; elevation of sea levels; and an increment in the frequency and severity of extreme weather such as hurricanes, or opposite phenomena, such as floods and droughts due to the increment of water vapour in the atmosphere as a consequence of higher evaporation rates caused by the increase in temperatures. In the last few years, European citizens have started to feel the severity of such phenomena with millions of euros in damage and, unfortunately, loss of lives from, for example, the floods in central Europe in the summer of 2021.

OBSERVATION OF EFFECTS

The effects of climate change affect all life forms on Earth with severe and, in many cases, irreversible consequences. Increasing CO_2 levels in the atmosphere extend growing seasons, which results in global greening and, at the same time, heat waves, large forest fires and drought reduce the ecosystems' diversity and productivity. These combined effects are expected to drive the extinction of many species (Turner et al., 2020). The temperature in the oceans is rising at a lower speed than on land; however, a faster migration of life forms towards colder water regions has been observed. In the same way, heat waves are affecting a wide range of organisms such as corals, kelp, and seabirds.

Climate change will also have an impact on human health. Extreme weather phenomena have a direct impact on injury and loss of life, reduced agricultural productivity will result in undernutrition in many developing countries, and a warmer climate will expand the areas of dispersion of several infectious diseases, such as dengue fever or malaria. Rising sea levels, as a consequence of ice melt, would flood many coastal areas and permanently submerge some islands. Unfortunately, most of these effects are unevenly distributed, affecting mainly disadvantaged people in developing and developed countries which will increase inequality. In fact, current inequalities between men and women, between rich and poor, and between different ethnicities have been observed to worsen as a consequence of climate variability and climate change (Hallegatte et al., 2016).

HOW TO COMBAT CLIMATE CHANGE

The main global effects of climate change -global warming, rising sea levels and extreme weather phenomena- will continue in years to come. However, it is still in humankind's hands -through mitigation- to reduce the activities that increase the emission of greenhouse gases to try to slow down their advance and move away from the point of no return regarding the effects of climate change.

Mitigation -limiting climate change- consists of reducing greenhouse gas emissions and removing them from the atmosphere (NASA, 2021). To achieve this objective, it is necessary to reduce activities that release greenhouse gases to the atmosphere -the burning of fossil fuels for electricity, heat or transport, that actually constitutes 80% of energy sources- which involves systemic changes -long term decarbonisation- at the global level to accomplish the reductions all countries have committed to in the International Paris Agreements (United Nations, 2015, 2021). At the same time, the rapid and significant development of renewable energy sources -solar and wind power, bioenergy, and geothermal energy- accompanied by an improvement of their efficiency, is also necessary. An additional strategy is to increase sinks to accumulate and permanently store CO_2 gases; oceans, soil and forests, thus, restoring natural ecosystems by reforestation.

SCIENCE, R&D AND INNOVATION IN ACTION

THE DIFFERENCES BETWEEN CLIMATE AND WEATHER

The main difference is a measure of time. *Weather* is what conditions of the atmosphere over a short time and is the subject of meteorology and the object of study and divulgation by meteorologists. On the other hand, *climate* is how the atmosphere "behaves" over relatively long periods of time and is the subject of climate science and the object of study of climate scientists who investigate and teach the dynamics of the earth's climate from a multidisciplinary point of view including meteorology, physics, oceanography, chemistry and even geology and biology. Their expertise has evolved to interact with theoretical domains of ecology and evolution and to develop computer systems (Parker, 2018).

Science must become the driving force to face climate change and its consequences. Science has played a significant role in the early stage by accumulating data that allowed the observation of global warming, identifying the causes and developing the models that predict its consequences. But now, science must play a decisive role in providing solutions. Many of the proposed solutions require the development of new and more efficient processes (i.e. CO_2 capture) that allow green and fair decarbonisation solutions to reduce greenhouse gas emissions and the expansion of renewable energies. Science must also investigate and provide solutions to reduce consumption and food waste by designing new circular bioeconomy processes.

SPEECHES THAT FLOW FROM DIFFERENT SETTINGS THAT SHAPE OUR LIVES

THE SECTOR OF INNOVATIVE AND RESPONSIBLE COMPANIES

This sector is of great significance for understanding and challenging such a complex and transversal problem as climate change that, through its increasing and more dramatic effects, has evolved into an emergency which has been identified as an *environmental pandemic* (Rey Rocha & Muñoz Ruiz, 2021a, b). In-depth analysis of the sector requires a broader and more ambitious research programme than we can afford at present. However, it is possible to approach that analysis by adopting the well-known "case study" methodology.

BILL GATES IN THE ARENA OF CLIMATE CHANGE COMBAT: THE PUBLICATION OF A BOOK ON SCIENCE AND TECHNOLOGY COMMUNICATION

Fortunately, that approach can be backed by the relevant representation of Bill Gates: he is one of the greatest fortunes of the economic world, founder in 1975 of Microsoft, a collaborative enterprise with Paul Allen, his childhood friend, and recognised as an experienced entrepreneur and user of technologies and innovation. As a leader of innovative and responsible companies, Gates performed accordingly by choosing, as a follower of social responsibility self-regulation that can be seen by his creation of the Bill & Melinda Gates Foundation, the dissemination of informed communication.

The Gates' interest in the process of climatic change became apparent with the publication of a book (Gates, 2021), both in paper and *e-book* formats*,* at the beginning of 2021 with the robust editorial support of The Penguin Random House Group for the Spanish version, the first edition of which was published in February of that year. Clearly, the original title in English, "*The Solutions We Have and the Breakthroughs We Need"* -advocating rational thought-, suits the purpose and contents better than the Spanish version "*Cómo evitar un desastre climático" (How to avoid a climate disaster)* -which appeals more to emotions.

In any case, the purpose and objectives of the publication are quite clear. On the one hand, there is a dedication, preceding the text, to "the scientists, innovators and activists" as a valuable introduction to a protocol which collects the knowledge on how the five questions that the author considers are mandatory in any conversation on climate -exchange of points of view- have been dealt with. Introduction to chapter three deserves particular attention since it is like a mirror of the protocol and method that reflects the book's essence. In the first sentences of that chapter, Gates states that the data on climate are difficult to understand and are frequently devoid of context, and admits that, over time, he built a mental framework and developed a certain intuition to know whether a figure was big or small, and how expensive things could be, which helped him to identify the most promising ideas.

Thanks to this strategy, the author has been able to develop a complete analysis throughout five chapters, from the 4th to 8th, of the big issues accompanying and shaping the evolution of innovations to fulfil the needs of the transition towards modernity: connection and electricity; how we manufacture; how we cultivate and breed (food production); how we move; how we heat and cool.

TWO MAIN TARGETS

It is clear that Gates' book is a significant contribution to the field of science and technology communication on climate change. One of the main assets of this work is the clarity and courage with which the problem is stated. The introduction entitled "51 billion to zero" shows *ab initio* two numbers related to the climatic emergency: fifty-one thousand million is the approximate number of tones of greenhouse gases contributed by the world to the atmosphere. Within small annual variations in these figures, this is what Gates defines as *the current situation*. The second number is zero, the subject dealt with in chapter one, where the author recognises that he employs the term *zero* in an imprecise manner (pp. 31). With such a statement, he enters into the realm of contradictions, permeating the problem which reveals the limitations of the book. He says that it is necessary to reach the objective of zero emissions -on the basis of substantial and weighted evidence- but at the same time, the task is considered colossal. This recognition is a contradiction in itself because, in the best case, that implies that all the processes for attaining zero emissions should be slow.

Two more worrisome facts are very clearly expressed in the book in chapters 1 and 2 -titled: "Why zero?" and *"This will be hard*" -. Chapter one ends by suggesting two processes to avoid the bad consequences of what we are seeing in the climate today: *adaptation* -minimise the impact- and *mitigation*, considering this second process more decisive, though, to achieve this, the rich countries, through innovation and research, "will have to achieve zero net emissions before 2050". Immediately, seventeen pages of chapter two are dedicated to describing the main pitfalls humans will face to attain such a goal.

A PLAN BASED ON TECHNOLOGICAL OPTIMISM AND EXCESSIVE DO-GOODISM

In spite of the many drawbacks on the way to counteract climate change, Bill Gates has not hesitated in his book to present a plan under the impulse of his technophile enthusiasm, love for innovation processes and sustained by his self-sufficiency as an economic and philanthropist leader. He proposes a plan for that goal, unfolded in the last third of the book: chapters 9 to 12. The very title of Chapter 9 "Adapting to a warmer world" leads to a feeling of melancholy because it doesn't only reflect a certain contradiction to what he said at the end of the first chapter but recurs to a list of initiatives sustained by blind confidence in innovative technologies and in do-goodism beyond the hopes of people changing their consumer habits. While the author remembers, in the text, that we must reach zero emissions and, to achieve this, we need a great effort regarding innovation, this will not bear fruit from one day to the next, as the sustainable products he has been mentioning would take decades to scale up enough to make a significant difference, and meanwhile, climate change is already affecting persons from all the world and all purchasing powers.

Too many projects to manage and excessive trust in citizen willpower, if it does exist! (Sampedro, 2021).

THE ROLE OF POLITICS AND CITIZEN´S PARTICIPATION

Gates is a socio-economic leader, an enthusiast technophile, able to promote and propose innovations, but he is also neither ingenuous nor misinformed. For this reason, three chapters form a strategic set on how to achieve the emission-zero goal: Chapter 10 stresses the importance of governmental policies, Chapter 11 expands the plan to reach zero emissions which is also the recognition of a time limitation because the date for this target is moved to 2050. 2030 is, therefore, declared as an unfeasible objective. Regarding the plan's contents, there are no surprises: it is a plan that follows the text to the letter, all measures rely on innovative technologies, and most of them are associated with institutional initiatives supported by funds from the Foundation and related organisations. The plan shows confidence in the laws of the market but at the same time accepts neo-Keynesian support from the public domain and proposes placing hope in the regulatory processes and in policies that will promote a multitude of standards, extending from the carbon price to green products, including the promotion of clean electricity or green energy and the rejection of old and inefficient ways of energy production.

In an excess of self-sufficiency, the plan analyses the potentialities of the different types of governments, ranging from the federal model to the local, in order to implement the measures proposed. A fascinating analysis, but it poses a question: ¿Is this more than wishful thinking?

Last but not least, Gates, as the leading agent of an industry devoted to connecting individuals throughout all the world, cannot forget, ignore his influential roles in current societies. He deals with them in Chapter 12 (“What each of us can do”), exploring their actions as citizens, consumers, entrepreneurs or employees.

CRITICAL REFLECTIONS FROM MODESTY AND RESPECT

It is obvious that Bill Gates and his book deserve respect and that its review must be approached with the acknowledgement of analysts’ modest influence. Communication processes may help to increase the social interest and reinforce the response of citizens to the environmental emergency, which has resulted in climate change becoming a pandemic (Rey Rocha & Muñoz Ruiz, 2021a, b).

In spite of the strong editorial campaign, the book has not obtained the public success expected. A criticism on that point can rest on the hypothesis that the book reveals the technical, political and economic aspects adequately but lacks any perspectives or visions related to humanities, social sciences and cognitive sciences, as well as to the ethical dimensions of the innovation and technological instruments and decisions applied under evolutionary tensions. There are no references to education, collective intelligence or epistemic surveillance as fields of social experimentation.

Gates’ commitment to fighting climate change is nevertheless apparent. On the 22nd of August, he decided to donate 1,500 million dollars to that goal.

CORAL REEFS: WATCHERS AND VICTIMS OF CLIMATE CHANGE

The source of information and inspiration is in epistemological terms the same as that of the previous case: the high scientific divulgation, science communication based on facts and unhurried reflection. The present case is supported by the historical magazine *Scientific American* and its Spanish version, *Investigación y Ciencia.* The issue under consideration is that of July 2021, dedicated, as the cover shows, to coral reefs and the effects of climate change on them (Investigación y Ciencia, 2021). The title for the issue is "*Al rescate del coral. Una nueva estrategia para detener los efectos del cambio climático*" (*To the rescue of coral. A new strategy to stop the effects of climate change*).

CORAL REEFS

These elements of nature are one of the wonders of the underwater world: they are formed by stony corals usually growing in marine waters low in nutrients and preferentially warm, shallow, clear, sunny and choppy. Taxonomically, they are classified as animals made of polyps that look like anemones.

From the practical side, it is worth remembering that they provide economic support to activities related to tourism and the primary sector, such as diving, fishing and the protection of the coastline. Their annual economic value has been estimated at 375 billion dollars. They cover around 285,000 square kilometres of the seabed. In the media and in ecological terms, coral reefs have been protagonists due to their fragility as ecosystems and high affectation from climate change as a result of their extreme sensitivity to the seawater temperature. Thus, they serve as visual gauges (indicators) and are victims at the same time of this environmental emergency

THE ARTICLE: PARADOXES AND LESSONS

The text offers interesting features with respect to communication and narrative strategies. First, following the strategy adopted a few years ago by the editorial policymakers of the American magazine, the article is not written by the research team as has been the case for decades but by a scientific journalist, Elizabeth Svoboda, specialist in biology and psychology; it does not describe a complete story of a scientific success but a new and extremely glamorous experiment which has been running for several decades after the verification of the problems faced by coral reefs after the greenhouse effects. A second and paradoxical fact deals with where the experiment is taking place: it is run in a laboratory of the gigantic AquaRio aquarium in Rio de Janeiro with the intention of improving the possibilities of survival of the coral reefs all over the world - the current president of Brazil, Jair Bolsonaro, is not precisely a fan of ecological and scientific projects, endeavours and initiatives.

TITLES AS INSTRUMENTS TO DEVELOP EDITORIAL STRATEGIES AND SIGNS OF IDENTITY

From the editorial framework, there are lessons to confirm, such as those derived from the analysis of Gates' book and some to learn. The story of the titles also applies to this article in the sense of revealing editorial strategies. As in the previous cases, the title of the English version: "Will Probiotics Save Corals or Harm them?" concisely reflects the contents of the article: "bacteria are helping corals in the laboratory tests but risks rise as treatments are applied in the wild".

Meanwhile, the Spanish version uses three titles depending apparently on the potential audiences targeted and profiting from the independence of the editorial team. One is in the cover of the issue: *Al rescate del coral: una nueva estrategia para detener los efectos del cambio climático* (*To the rescue of coral. A new strategy to stop the effects of climate change*), seems to address the general public. The second, in the dossier or index of the articles and in the first two infographic pages (18-19), the title is: *"Probióticos para salvar el coral: se están empleando cócteles de bacterias diseñados para mejorar la supervivencia de los corales" (*Probiotics for saving coral: designed cocktails of bacteria are employed to improve coral survival*)*, which is the nearest to the original though with important differences: it is not interrogative, it hides the potential environmental consequences of the probiotics in the wild; it appears to address the interested people, the experts and the scientific repositories and data bases. Thirdly, the Spanish editors have chosen a metaphoric title for the text, describing the place where the experiments are taking place; the strange title is as follows: "*Pastinacas y tiburones de arrecife de puntas blancas se deslizan ante los ojos de los visitants"* (Stingrays and white tip sharks glide before visitors' eyes).

A CINEMATOGRAPHIC NARRATIVE

The article breathes out a certain flavour of originality resulting from the changes in editorial strategy as discussed above. It starts describing how the laboratory on the fourth floor of the aquarium is organised: twenty rectangular tanks each about 20 centimetres wide are arranged on that floor. Each one houses a colourful assortment of coral fragments. The experiments are operated by a Brazilian team that works exploring the effects of the several ways of providing cocktails of designed probiotics to the coral fragments. The former experiments were carried out and published in 2015 by Raquel Peixoto, leader of the group, who pioneered the fight against coral bleaching. She feels that before the threats to corals due to the rise of seawater temperature, as was stated by experts in 1990, it is deemed necessary to treat the corals with bacteria in the natural marine milieu, even if these experiments may induce changes in the entire ecosystem. Peixoto has declared: "It is not comfortable for a scientist to be involved in this …. But we have to act. If we don´t, it will be too late".

This first part of the article depicts a panorama that sounds like a "mini blade runner" for the situation of the subaquatic domain. Carlos M. Duarte, marine ecologist who is now at the King Abdullah University of Science and Technology (KAUST) has expressed his fears in respect to the temporal solution: "we have a very narrow time window, a decade, "to respond to the report of the United Nations Environment Programme where it is stated that "about 2034, the majority of the coral reefs of the planet will suffer an annual period of bleaching, mainly due to ocean warming, and that without any help, they will have disappeared in 2100". By the way, it seems interesting to mention that Raquel Peixoto now works as a marine microbiologist at KAUST.

SCIENCE ON STAGE

Once science comes into play, interested readers will find a series of experimental approaches ranging from repairing coral reefs bleaching, resorting to technologies applied in the plant kingdom to the exploration of the cooperation potential between polyps and microbiome to overcome the risks of coral reefs becoming skeletons without any hope of survival. The restauration processes are slow and expensive and the processes of cooperation related to the metabolic processes of nitrogen and oxygen by the intermediation of bacteria may attain partial solutions, in particular avoiding the losses of tissue and protecting against some diseases, but they don´t seem to contribute to a general cure.

Based on previous analytical analyses, it might be postulated that the process of research aimed at saving coral reefs responds to the profile of an evolutionary story which will provide a theoretical and experimental framework for understanding and extending further analyses on this and related topics. This assumption is supported on four arguments: the survival of coral reefs is the main common target; there is agreement to research the origin of the problem, which points to profound environmental alterations of the natural living site of corals; cooperation and hybridisation between polyps and microbiome are essential pillars for a satisfactory life cycle of coral reefs; experiments on the high seas are fundamental to advance regardless of the common target. Raquel Peixoto strongly supports this approach.

It is precisely this line of work that has raised ethical concerns in relation to the risks of using probiotics in the natural sea habitat. This issue is dealt with in the last part of the article as was mentioned in the original English title. These ideas (Muñoz, 2008; Muñoz van den Eynde & Muñoz, 2019; Muñoz van den Eynde, Rey Rocha & Muñoz Ruiz, 2021) led to the proposal of a consequentialist ethical setting based on values, responsibility being a critical one for the current dilemma. Warning, this scheme is very far from any presumptuous utilitarianism.

For us, evolution is linked to the concept of “significant social environment” (Muñoz, 2015) that embraces three elements: nature (living beings plus environment), culture (including science) and ethics.

LAWS, POLICIES AND HUMAN ACTION: THE SPANISH LANDSCAPE

The global scale of climate change and the climate emergency determines the scope of the corresponding regulatory and legislative framework concerned. This is particularly true in those countries that have subscribed to international agreements on these matters.

Within the European Union, climate change policies concern the Member States, as well as their different administrations and regional and local institutions[32]. Consequently, the various administrations are concerned, in their respective areas of competence, in the development of

32 Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community’s greenhouse gas emission reduction commitments up to 2020.

policies, regulations and laws aligned with the environmental objectives subscribed to by the European Union within the framework of these international agreements and established in the Union's policies and recommendations.

The laws on climate change set the legislative discourse in this area and establish a regulatory framework to regulate actions, mainly in relation to the reduction of greenhouse gas emissions and consequently the mitigation of their consequences.

FRAMEWORK FOR ACTION AT DIFFERENT PUBLIC AND PRIVATE LEVELS. THE CASE OF SPAIN

The interaction of the competencies at different administrative and geographical levels can be perceived insofar as the laws respond to countries' compliance with their international commitments against climate change. In Spain, together with the Spanish Government's Law on Climate Change and Energy Transition[33], several autonomous communities have already drafted or are working on their own climate legislation (Regueira, 2021). The most advanced of them, the Valencian Community, has recently approved the preliminary draft of the Valencian Law on Climate Change and Ecological Transition34.

This chapter is not intended to add to the existing analyses, signed by sufficiently qualified experts, of the various laws that have been adopted or are in the process of being drafted or processed. Nor to carry out a comparative analysis of them. Rather, its aim is to consider the possibilities that these regulatory frameworks provide to mitigate and combat climate change. Instead of climate change, it would be more appropriate to say against environmental degradation, which constitutes what has been identified as an *environmental pandemic* (Rey Rocha & Muñoz, 2021a, b), an environmental disease that affects the entire planet and is, therefore, pandemic.

A reading of the above referred legislative texts makes it possible to identify various areas and opportunities for action by the different administrations. One example is the approval of incentives for the introduction of renewable energies and the promotion of self-consumption. Coordinated action is exemplified in the aspects that concern cities. The national law establishes that urban planning must take climate change into account and that all municipalities with more than 50,000 inhabitants -as well as those with more than 20,000 inhabitants whose air quality is not good- must include the approval of low-emission zones -linked to their sustainable mobility plans in the case of the former- which can only be reversed with a favourable report from the regional government. Climate change must also be taken into account in hydrological planning in a politically decentralised State such as Spain, in which "the ownership of administrative competencies in water matters is conditioned by the extension and territorial nature of the water basins" (Fanlo Loras, 2010) and whose competencies are distributed, in different ways, between the Central Administration and the

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33 Ley 7/2021, de 20 de mayo, de cambio climático y transición energética [Law 7/2021. On climate change and energy transition. 2021, May 20]. Boletín Oficial del Estado (BOE), 121 (May 21), 62009-62052.

34 Anteproyecto de Ley del Cambio Climático y Transición Ecológica de la Comunitat Valenciana [Preliminary draft Law on Climate Change and Ecological Transition of the Valencian Region].

Autonomous Communities (Gobierno de España. Ministerio para la Transición Ecológica y el Reto Demográfico, 2021).

The laws also establish areas of action for the private sector, although, pending the development of the law, these do not always go beyond the merely administrative and bureaucratic sphere. This is the case of the duty that the Spanish law imposes on large companies, financial institutions and insurance companies to "prepare annual reports on the risks to their activity arising from the transition to a sustainable economy and the measures adopted to address these risks". The same bureaucratic requirement is established for public sector institutions in sectors such as finance and energy. Thus, the Bank of Spain, the National Securities Market Commission (Comisión Nacional del Mercado de Valores) or the General Directorate of Insurance and Pensions Funds (Dirección General de Seguros y Fondos de Pensiones) "will have to submit every two years a joint report on the degree of alignment of the financial sector with the goals of the Paris Agreement and the EU, as well as an assessment of risks for the system". State-owned electricity and gas system operators will have to do something similar, as will the Logistic Company of Hydrocarbons (Compañía Logística de Hidrocarburos).

On the other hand, citizen action has given ample proof of its capacity for action in the fight against climate change and in defence of the environment, based both on traditional modes of participation and on the capabilities offered by information technologies, particularly social media. Citizen action on environmental issues is characterised, as in many other cases, by anticipating a political and legislative reaction. But individual actions and social movements to preserve the environment, however necessary and effective, are not enough. As Naomi Klein points out (González Harbour, 2021), we need international and national strategies, enforceable laws and government support; we need "governments that clearly present a plan to the population" and say, 'This is not just up to you, it does not depend on you being perfect; this is what we are going to do as a society to change, and we are going to give you these supports". It remains to be seen to what extent the laws on climate change or environmental laws, which have been widely criticised by different agents and social sectors for their lack of ambition and the delay in their drafting, processing and approval, have any capacity and usefulness in driving, supporting or coordinating citizen initiatives. For instance, the Spanish law establishes the creation of "a committee of climate change experts" to evaluate and make recommendations on policies and measures for the transition. Its members will prepare an annual report that will be "sent to the Congress of Deputies and submitted for debate". In addition, the Government will create a "citizens' assembly on climate change", which will seek to encourage the participation of society in the fight against global warming.

CLIMATE CHANGE AND TRANSITION: ENERGY OR ECOLOGICAL?

The different laws here referred coincide in their focus, expressed in the title, on climate change. With the exception of the Asturian law -known as the Environmental Quality Law- all of them refer to climate change in their titles. But they differ in their conceptualisation of transition, focused on *energy* in all of them, except in that of the Valencian Community, which at least in its initial wording is committed to an *ecological* transition. A priori, this gives the Valencian law a more generic approach than can be assumed for the others, as it does not focus solely on energy transition. However, the distinction between both energy and ecological transition is not always clear in its text, and even in the definitions section of Annex I, energy transition is not defined -perhaps because it is considered obvious- and the definition of ecological transition focuses on energy aspects -decarbonisation, reduction in the use of fossil fuels, and their replacement by alternative renewable energy sources-. It, therefore, ignores other aspects that should undoubtedly be considered in an eventual transition described as ecological, such as waste reduction and management or the fight against biodiversity loss. The ambiguity about the concepts of *ecological* and *energy transition* is evident throughout the articles of the Valencian law, which associates the ecological transition with a change not only in the energy model but goes further to talk about lifestyle and the social, economic and environmental model. The draft law marks its theoretical framework and scope of action, within the context of a green transition, in article 143, in which point 2 identifies, along with actions targeting energy, others in terms of efficiency and water saving, biodiversity conservation, reduction of impacts on health and on animal and plant health, the protection of the population against the increased risk of extreme weather events, forest management, research, innovation and education on climate change, and the transformation of the agro-industrial model and environmental and ecosystem services.

In short, the draft law of the Valencian Community implicitly recognises the magnitude of the problem, which, as previously argued, goes beyond the merely climatic sphere, since it is an environmental emergency or pandemic, which requires a cross-cutting approach, within the framework of proposals for an ambitious transition, that should be labelled *ecological* rather than using the more restrictive and limited term, *energy*.

A more explicit recognition, from the title itself, of the environmental and not only climatic magnitude of the complex problem being legislated on would provide the legislative texts with a more marked pedagogical character in this sense, by transmitting to society the magnitude of the challenge facing humankind, which various authors, such as Moises Naim, consider, together with the covid-19 pandemic, the two most important problems facing humankind in the 21st century[35].

The Spanish national law also provides for measures to protect biodiversity and its habitats from climate change and the preparation of basic guidelines for the adaptation of Spanish natural ecosystems and wild species to climate change. It also requires the government to incorporate measures to reduce the vulnerability of agricultural land, forests and woodlands to climate change, including the preparation of a vulnerability map.

SCIENCE AND R&D IN LEGISLATIVE DISCOURSE

Science and scientific research have a place in the laws on climate change and energy/ecological transition. Both laws mentioned here include an argumentation, in their respective preambles or

35 The international commentator Moises Naim replied to Angels Barceló on Cadena SER radio station that 9/11 was a great problem (geopolitical, we would add) for the 21st century but that there were already two more important problems: climate change and the pandemic, which by the way is related to climate change, we add again.

explanatory statements, in which the scientific evidence and the scientific-technical reports of the relevant international organisations on the subject, such as the conclusions of the scientific community contained in the special report of the Intergovernmental Panel on Climate Change (IPCC), are included.

Likewise, the Spanish law, in a declaration of intentions, links the fight against climate change and the energy transition to R&D. But this relationship, as stated in its preamble, is focused on the establishment of mechanisms to support industry, although, on the other hand, research, development and innovation are considered, together with education, as essential issues for the involvement of Spanish society in responses to climate change and the promotion of the energy transition. Article 36 promotes the inclusion of climate change and energy transition among the priorities of the Spanish Science and Technology and Innovation Strategies and in the State Plans for Scientific and Technical Research and Innovation.

TOWARDS A NEW SOCIAL PACT

The inclusion in the laws of a reference to the role of governments, institutions, social agents and society as a whole is to be welcomed, as humankind faces a problem whose solution requires a global approach and the cross-cutting involvement of citizens and society as a whole and of the different sectors and actors, which must take into account considerations relating to changes in development and growth patterns, behaviours, and consumption habits, and considerations of equity and solidarity.

Apart from the transformation of the economic model, to which it devotes a certain level of detail, the Spanish law echoes the new social contract stemming from international agreements, particularly the most recent 2015 Paris Agreements, the development of their rules in Katowice and the 2030 Agenda for Sustainable Development.

Both laws, the Spanish and Valencian, echo the differential effects of climate change and the measures aimed at the transformation of the economic and social model on different groups and the need to address the most affected and vulnerable of them. In particular, the Spanish law advocates "the equitable distribution of wealth in the decarbonisation process" in a "just transition for the most vulnerable groups and geographical areas... towards a more environmentally friendly production model that is socially beneficial".

In this sense, regulatory frameworks reflect the absolute relevance of and the existing framework for citizen action in terms of values, reduction of consumerism, recycling, waste reduction, more sustainable and friendly cities, reduction of mobility and of the use of polluting means of transport for commuter mobility, environmental awareness, etc. Linked to this point, both laws discussed here echo the importance of education, in line with article six of the United Nations Framework Convention on Climate Change -recognised by the 2030 Agenda as the main international intergovernmental forum for negotiating the global response to climate change- which includes the need to develop public education and awareness programmes on climate change and its effects, public access to information, public engagement and the qualified training of scientific, technical and managerial personnel. This is also reflected in the article referring to the Social Awareness and Socio-economic Training Programme for the Ecological Transition, and in one of the targets of the United Nations Sustainable Development Goal 13, which states the need to "Improve education, awareness and human and institutional capacity with respect to climate change mitigation, adaptation, impact reduction and early warning". The Spanish law, in its Title VII, addresses education and training for sustainable development and climate care as an issue "of essential importance for the involvement of Spanish society in the responses to climate change and the promotion of energy transition". Similarly, the Valencian law recognises that “education has a strategic role in the just ecological transition, as society as a whole has to assume in their lifestyle the profound changes resulting from a new social, economic and environmental model”. To this end, “the Law seeks, through the tools of environmental education for sustainability, to make people and organisations aware of the severity of climate change and to prepare them to adopt behaviours, both personally and collectively, in line with the reduction of the ecological footprint and decarbonisation".

REFLECTIONS, DOUBTS AND THE CLOUD: FROM RISKS TO COMPLEXITY

This attempt, regarding climate change, to deal with the relationships between the scientific and technological narratives and the threats experienced by the nature of that phenomenon, may hurt in terms of social debate. This risky situation leans on arguments, not excuses, as follows. First, the intellectual limitations implicit in an analysis by authors who are not climate change experts, but interested followers (see above). This hindrance can be aggravated by a shift in the debate on whether climate science communication should adopt a pessimistic style, as usual, or evolve toward an optimistic style.

Second, the great complexity of the issue at stake in the West: the analysis of the rational discourse about an environmental pandemic while at the same time the West intends to overcome a health pandemic of extraordinary economic and social consequences with the will of recovering the prepandemic normality without any effort, personal o collective, to change abnormal and abusive behaviours.

In third place, the extremely volatile social settings resulting from the neo-capitalist strategy that during the last four decades has imposed, by a combined effort of influential economic and media actors, a process of globalisation. This process gave some positive results, such as a slight reduction of poverty globally and an apparent better international interchange of goods. But in the real evaluation, that strategy has resulted in a total failure in terms of human equity accompanied by the two crises, the financial one of 2008-2013 and the pandemic of covid-19, still ongoing. Societies have been shocked by the result: increasing inequalities, the violation of social justice values, the progressive weakening of the concept of the welfare state and even in the geopolitical realm, as shown by the Afghanistan fiasco.

So, the social milieus evolved semantically as never before in the history of human societies. Thus, they have been renamed so frequently as: risk society (Ulrich Beck, 1986); information society [based on the technological capabilities for social, cultural and economic activities, (Castells, 2004)]; liquid society (Bauman, 1999); knowledge society [aiming the critical and selective appropriation of this human power in order to complete the satisfaction of the economic needs and the full development of human beings, (Drucker, 1969)]; or post-social (Touraine, 2016).

The social situation has evolved in the XXI century towards a greater complexity with citizens and societies embedded in uncertainties, irreversibility of environmental, health or social conditions as well as experiencing pathological processes in the communication domain. Looking for metaphors more prone to being understood by a restless citizenship, names such as *muddy society* or *quicksand society* can be proposed.

TRILEMMA KIS[36] (KNOWLEDGE, INTERESTS AND EMOTIONS), WAKEFULNESS OR MIRROR

It would be presumptuous or perhaps wilful trying to propose a solution to the problems outlined in the text.

However, in a step towards optimism, an instrument can be offered to analyse a given problem or situation and, even on the basis of a good diagnostic, provide insights for eventual solutions. The instrument is a trilemma built on triads: the first one accounts for three main processes or situations which characterise the current societies: uncertainties, irreversibility and communication defects leading to misinformation as a blend of fake news, the bullshits and interested lies. A second triad rests on three scopes that interact as frameworks for understanding climate change: evolution, ecology and ethics. The third one consists of the functional mental processes which are essential for taking decisions: knowledge (human power or ability), interests (human utility) and emotions (human sensations for adaptability).

To close this first attempt to analyse complexities and interrelationships, a new insertion into semantics by pointing out that all the proposals to counteract the environmental pandemic should not be supported on affirmative sentences but may also count on negative ones, as shown in the following statement.

Complex issues cannot be understood and solved under monodisciplinary perspectives and visions according to the prevalence of narrow selfish interests without taking into account cooperation and altruism and emotions no modulated through values such as responsibility, trust, empathy and social justice.

36 This trilemma has been thought and proposed in Spanish as a political instrument and with an innovative methodology (See Muñoz van den Eynde, Rey Rocha & Muñoz Ruiz, 2021).

THE MORE POPULAR THE CULTURE, THE MORE PUBLIC THE ENGAGEMENT: THE YŌKAI AMABIE TRADITION AND THE HEALTH CAMPAIGN DURING COVID-19

María J. Miranda Suárez

This chapter has two aims. First, it analyses the impact of the irruption of non-Western cultures on health engagement campaigns by means of the Amabie challenge. Second, it explores the impact of historical and popular Japanese stories on citizens and their praxis in the context of the COVID-19 pandemic. The alliance of the Japanese Ministry of Health with popular culture was one of the most efficient ways to develop innovative campaigns on antimicrobial resistance in this country. This open-minded approach made it possible engaging the largest possible audiences in the management of the pandemic by means of Yōkai Amabie. There is no doubt that the 21st century has begun with a major hypermodern crisis, but Amabie challenge became a virtual signifier of solidarity by which people remain connected to Yōkai in terms of belief but also in terms of playfulness. One of the features of Yōkai's creatures is the liminal space defined by popular culture, health and public engagement.

INTRODUCTION

One of the major priorities of the Japanese Ministry of Health, Labour and Welfare was working on creative health campaigns in order to engage with the public in pre-COVID times. Since 2016, they have found the use of anime and manga characters to be powerful tools for communicating with the public. These campaigns without doom and gloom messages in which fictional heroes take on public health treatments were praised by international institutions such as the World Health Organisation (2017). The alliance of the Japanese Ministry of Health with popular culture was one of the most efficient ways to develop innovative campaigns on antimicrobial resistance. This open-minded view made it possible to engage the largest possible audiences during the COVID-19 by means of Yōkai Amabie.

Popular culture is a forum for exchange and negotiation between the power which imposes hegemony and the forces which resist it. In every popular cultural practice there is a combination of opposing interests. Furthermore, the notion of postmodernity had a fundamental impact on the study of culture since it essentially questioned the distinction between high culture and popular culture through the effects of signifying practices. Initially postmodernism was a critique of the predominance of avant-garde aesthetics, which was meant to be radical but which ended up becoming gentrified and entering the museum circuit. Indeed postmodernism was born as a response to the aesthetic canons of modernity and ended up questioning the validity of the notion of the aesthetic cannon itself.

Disbelief in what had been the great Western metanarratives promising universal liberation (Lyotard, 1974) gave a chance to pluralities operating on social and intellectual scenarios. Postmodernity therefore points towards what is irreducible in the field of culture and society. There is no longer any universalising discourse which is efficient in unifying diversity and heterogeneity. Moreover, post-modernity distinguishes plurality as a store of cultural practices. In fact postmodernity is a consequence of post-industrial or consumer society, the society of spectacle and digital capitalism.

Indeed, Althusser affirms that ideology has no history which relates it to the definition of the unconscious since it is empty, purely a dream, an illusion which does not materialise into anything (Althusser, 2005). It is different from ideologies which do have history. On the contrary, it is omni-historical, a structure present throughout history in an immutable manner. This first description indicates that for the writer ideology is necessary in history, although it is a structure, beyond the forms it has historically taken. Althusser improves this definition by moving on to how ideology represents the imaginary relationship between individuals and their actual conditions of existence (Althusser, 2005). In ideology therefore we would not find the real conditions of existence reflected but rather the imaginary relationship of individuals with these conditions of existence, i.e. how individuals imaginatively represent to themselves the conditions in which they live. Althusser stresses that ideology is the reflection of an imaginary relationship. Despite the imaginary character of this relation however, ideology has a material existence which means that it does not belong to the realm of ideas but rather of actions since ideology is the cause of the individual's acting and participating in regulative practices, even in those cases in which he/she acts contrary to what he/she says or believes. Consequently, he mentions two theories which go together: there is no practice but in and by an ideology and there is no ideology but by and for subjects (Althusser, 2005). At this point, Althusser turns ideology into a format of subjectivity, a question which becomes central to the theory of cultural critique in authors such as the philosopher Judith Butler. These theories allow him to move on to the nodal point of how ideology addresses individuals as subjects.

The main aims of this chapter are to explore the Amabie challenge in order to analyse the impact that the irruption of non-Western cultures has had on the field of health engagement campaigns, and secondly to explore how historical and popular Japanese stories have an impact on the subjects and their praxis in these COVID-19 times.

THE PARADE OF YŌKAI

Yōkai are no longer exclusively a Japanese phenomenon of the past but a current worldwide movement. Yōkai initially emerged during the Edo period (1603-1868) which was a time of extraordinary development and literacy; a vibrant popular culture developed in urban centres such as Kioto and Osaka. In the Edo period a written literary record appeared to combine elitist and popular literature, driven by the emergence of a hedonistic culture in large cities and the popularisation of printing. It was at this time when so many of the attributes we associate with Japanese popular culture began to gain importance and these included Yōkai.

As monsters do, Yōkai are continuously changing. Literally in many ways and also figuratively they are shapeshifters that have been part of the cultural imagination for as long as history has been recorded. These diverse, mysterious, and weird phenomena have come to be known as Yōkai in Japan and this term has been translated in various ways. "Monsters" is a good translation as is "spirits" or "mysterious phenomena". These different renderings remind us is that the word Yōkai encompasses a broad spectrum from the concrete and tangible monster to the more amorphous abstract idea of a spirit or a mysterious phenomenon or merely something strange. Yōkai covers all these concepts as it is one of many words to express the same idea. Mononoke, an old word from the Heian period (794-1185) which is used in The Tale of Genji, provides an example. We also find the word Bakemono which has the same meaning as Yōkai but implies an ability to change form and shape (Dylan Foster, 2015).

Although these concepts are very complex, Yōkai may be seen as an entity which emerges from an event, a phenomenon, a feeling, a question; or perhaps something strange happens and you want to try to figure out what it is, which leads you to identify it, and to create an image or focus on an object.

During the Heian period there was a notion known as Hyakkiyagyõ, which means a “night procession of 100 demons”. The idea is that there are times and places that were infested by demons, a frightening, chaotic mass of strange creatures which were however undifferentiated and unnamed; a scary bunch of beings such as a Pandemonium. Gradually people started trying to describe them and to create images of them. Many picture scrolls from the Edo period based on earlier ones can be found. They depict numerous images of this huge group of strange creatures tramping along which leads to the notion of the Yaki Yaki, the procession or the Pandemonium of crazy creatures. People began to wish to identify them and to narrow them down in the sense of let's label, name and differentiate the individual. This is how the Pandemonium joined the parade, showing the incredible abundance and variation of Yōkai in the cultural imagination of the time (Dylan Foster, 2008).

There are literally hundreds of variations of individual Yōkai and hundreds of other kinds of Yōkai; an incredible diversity. During the Edo period this plurality was dealt with in two ways. In this sense Michael Dylan Foster distinguishes between *encyclopaedic* and *ludic* modes (2015). In the former the ideas and images were collected, classified, organised, and described. This is a serious process of organising information, a natural history project on our conception of many of the things in the world. The latter mode relates to another way to deal with Yōkai. This mode concerns telling stories about them, drawing them, playing with them, having fun with them, or creating new ones to add to the pantheon, which means being playful in a light-hearted, creative process of expressing information. From the Edo period to the present the notion of encyclopaedic and ludic modes can be found simultaneously in games such as Pokemon in which you collect cards with information which are exactly like encyclopaedic entries. In general terms Yōkai are in fact still part of contemporary culture in Japan and increasingly part of global popular culture as the Amabie challenge is today.

YŌKAI WARS IN WESTERN TIMES

Edward Said (1974) has become a major figure in so-called postcolonial studies which have dealt with culture beyond Western territories and the impact of colonialism. Said showed that the arrival of Western culture in distant lands also transformed the West's own cultural discourse. In a very interesting way he defines Orientalism as a set of discourses but with a real effect. Since the East is external to the West but is rather to be found within it, for Said it is not that the Orient was there and that the Europeans described it, but rather that the Orient was "made Oriental". However, the relationship between East and West, although discursive, was affected by power relations. In fact Said is interested in how the Orientalist discourse was tightly interwoven with political and economic institutions. Therefore it was not simply a fantasy but a discourse with a real effect on the lives of the subjects.

Based on the idea that culture is a breeding ground for conflict, he explored how the confrontations which accompanied colonial expansion throughout the world found their expression in literary, music, and ethnographic works. Said thus gives us a familiar definition of culture in which it is a kind of theatre where different political and ideological causes confront each other (Said, 1993). Far from constituting a placid corner of harmonious coexistence, culture can be a veritable dogfight in which causes are exposed to the light of day and pitted against each other. For Said, the great cultural works of the West shared the hegemonic ideology which construed colonial subjects as inferior to Western subjects. The study thus reveals itself to be very *Gramscian* and demonstrates that the most exquisite culture was involved in the conquest and subjugation of land and people.

Culture is thus an institution that reflects and reproduces power relations. In this way it creates split subjectivities, since the East orientalises the West at the same time that the West westernises the East, and this gives rise to the birth of what Said calls hybrid movements of counter-energy (Said, 1991), political and cultural movements which have called into question the totalising force of power. Culture, then, is a space where subjects find themselves subjected to the discourse of power. Sometimes they reproduce it, but sometimes they borrow it in order to make something different which can oppose the same ideology of which they are the result. The work of this professor of comparative literature had a special impact on the Anglo-Saxon world, which saw the birth of what have been called post-colonial studies, a discipline which researches the literature and culture flourishing in the territories which had been colonised, especially in the Anglophone world but also in the Francophone and Lusophone worlds.

The processes of colonisation and subsequently those of decolonisation gave rise to different cultural products. The colonial period thus generated a cultural elite which identifies with the values of the metropolis; despite the fact that they do not profusely describe colonial life, the hegemonic values belonged to the imperial enterprise which shelters them. The end of the Edo period came when Commodore Matthew Perry’s *black ships* appeared off the shore of Japan and with the advent of a scientific world. The Meiji Period (1868-1912) therefore begins with the arrival of outside influences en masse in the form of scientific thinking on supernatural phenomena. Indeed the Japanese government was forced to look at its own culture and found it to be rather backwards since their countrymen still believed in things which Westerners had rejected. A campaign against Yōkai was therefore introduced so as to declare them not to be Yōkai, but rather Shinkei, which basically means nervous disorders (Ohnuki-Tierney, 1984). There was a dismantling of all of this mythology which had been built up. The two main authors of the Edo period fought a kind of Yōkai war (Figal, 1999).

On one hand, Inoue Enryo decided to research Yōkai thoroughly and created what was called Yōkai gaku or Yōkaiology. He did this with a very specific purpose; he would define Yōkai and thus destroy them since Yōkai exist as the indefinable which lives in the shadows or hides behind the door. Enryo wished to lighten every shadow, to open every door, and to prove that Yōkai did not exist and were simply astrophenomena (tricks of the weather, tricks of the mind) and that actually believing in Yōkai amounted to a mental illness. His studies and his publications were so pervasive in the Meiji period in Japan that he was given the nickname of Yōkai Hakase or Professor of Yōkai as he attempted to dismantle all this folklore.

Yanagita Kunio opposed Enryo with a different point of view, believing that Yōkai represented in fact the very heart of Japanese culture. He considered that Yōkai were part of Japan's identity and were of great value; if Inoue Enryo succeeded with his campaign a very important characteristic of the country would be lost. He therefore created an opposing view of Yōkai, which was to identify and classify and essentially make the unknowable knowable. He therefore created Minzokugaku, which means folklore studies. Yanagita Kunio is best known for his book *Tales of Tono* (Kunio, 1910), a Japanese version of the Grimms' fairy tales. He had read what the Brothers Grimm were doing in Europe, how they were gathering, saving, protecting, and preserving folk tales. He decided that he very much wanted to do the same for Japan, collecting and gathering as many folk tales as he could before they were lost.

During the Showa period (1926-1989) people believed in Yōkai, but the latter then became more of an academic subject. They began to move into pop culture or return to popular culture as during the Edo period when they appeared in board games and children's games. They leap from folklore into a kind of modern pop culture. Shigeru Mizuki is a very important figure in the story of Yōkai and produced new versions in Japan's new emerging art form of manga. He became one of the early manga artists (Mizuki, 2019), aiming to retell Yōkai stories in this new easy format. His greatest contribution to Yōkai was in the 1960s with the character Kitaro, which was so popular that it exploded across Japan. In 1969 Kitaro was also adapted into an anime which further spread the fame of Yōkai (Mizuki, 2017). Another of Mizuki's achievements was not just creating Yōkai for animation but also for entertainment. He would also include in his books Yōkai quizzes or Yōkai files or pieces of information. He made a serious effort to use entertainment as a teaching tool for Yōkai which made children even more interested because it is always fun to do a quiz or find out how much you know about Yōkai.

To move forward to the Heisei period (1989-2019), producers of manga continued to be extremely popular and continued to keep Yōkai alive in popular culture. These producers include Rumiko Takahashi. She created the incredibly popular Inuyasha (Takahashi, 1996), which brought most of this world of Yōkai to the West. In the modern world of popular entertainment it is difficult not to have heard of Koyoharu Gotouge and her comic *Demon Slayer* (2016). Koyoharu Gotouge has taken our phenomena to a world stage. *Time* magazine drew up a list of the 100 most relevant people in the modern world, and Gotouge was probably the first manga artist ever to appear on this list. Demon Slayer has once again ensured that the Yōkai will continue into the Reiwa period (2021-).

WHAT IF AMABIE ALSO SAVED LIVES DURING THE COVID-19 PANDEMIC?

In February 2014 the Ministry of Health, Labour and Welfare held a survey of the awareness of Japanese people *Towards the Realization of Health and Longevity in Society* (MHLW, 2014). According to this survey, the number of people who caught "infectious diseases such as influenza" fell by half to 4.9% compared with the 11.3% of 2004 (Figure 8). In addition, "stress that causes mental illness" and "disasters and traffic accidents" were less prevalent. The reason for this is that in 2004 there was a great deal of interest in infectious diseases such as the outbreak of SARS (Severe Acute Respiratory Syndrome) and the number of patients with depression has been increasing in recent years. It is possible that many people's health has suffered. Moreover, the Great East Japan Earthquake struck in 2011 to increase awareness of the danger of such disasters. Since only 4.9% of people identified contagious disease as the most important threat, the MHLW decided to improve public awareness of the risk of infection by contagious diseases. During this pre-COVID period manga and anime characters became a powerful tactical tool as they have been enjoyed by several generations.

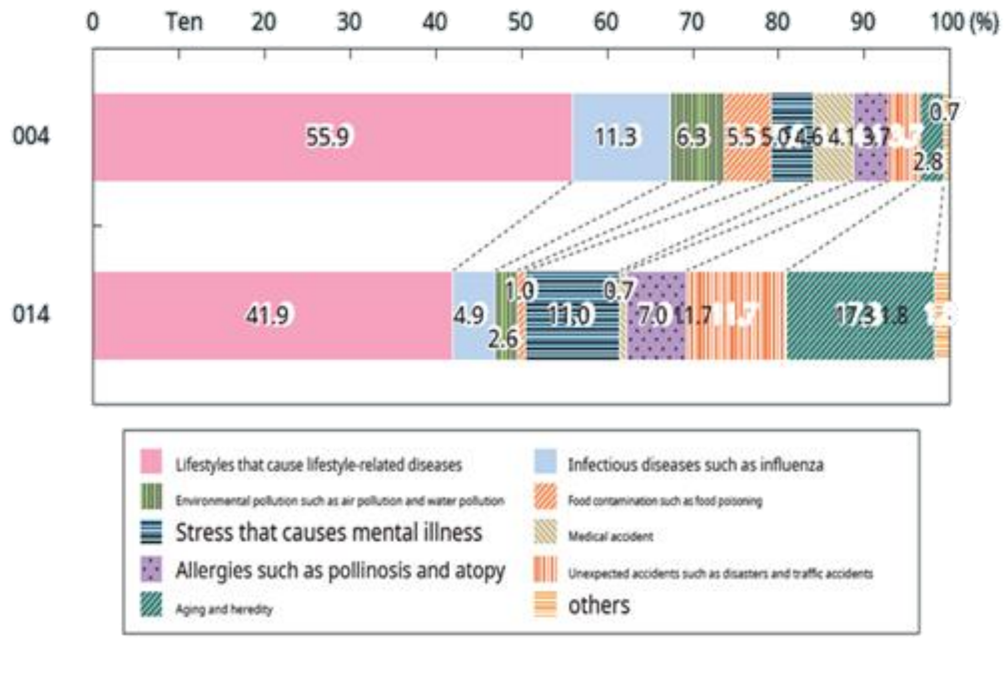

Figure 8. 2014 Ministry of Health, Labour and Welfare administration

Some of these campaigns were inspired by characters such as Pretty Guardian Sailor Moon (Figure 9), which was used to engage the public in the promotion of testing for sexually transmitted infections. During the campaign, her signature phrase “In the name of the moon, I will punish you!” was redesigned as “I will punish you if you don’t get tested (for STI)!”

Figure 9. Pretty Guardian Sailor Moon (@Naoko Takeuchi, 2016)

Mazinger Z (Figure 10) was another anime character used to raise awareness and promote prevention for measles infection overseas. In Japanese the main character’s name sounds similar to “Measles Will Be Zero” and this was exploited by the campaign to raise awareness of the fact that Japanese international travellers with a low immunity to measles are at risk of infection.

Figure 10. @Go Nagai/DynamicPlanning-MZFilmPartners 2017-2020

More campaigns were implemented during the pre-Covid period to address Antimicrobial Resistance (AMR). The use of popular culture in these campaigns changed the traditional public stereotypes of the MHLW to earn positive recognition from the mass media and the World Health Organisation. However, it is not easy to know which figure is going to be successful at the right moment. In order to understand why Amabie was the main protagonist in the COVID campaign, we must briefly introduce its history within the Yōkai family.

In 1819 the Jinja Hime was recorded by the scholar Katō Ebian in his diary *Waga koromo*; this is essentially the model of the Amabies for all the prophetic Yōkai to come. Katō Ebian records in his diary that this long fish, with a horn face of a woman and a sword tail, appeared and gave him the message that for the next seven years the harvests would be very abundant but then there would be a colori epidemic. However, those who saw its picture would be able to avoid hardship and live a long life. This is therefore the prophecy of the Jinja Hime which will be repeated in the following Amabies. Nowadays many people would translate colori as cholera. But cholera had not yet been introduced to Japan at the time. To the best of our knowledge it seems most likely from the description of the disease that colori was dysentery. This original picture of the Jinja Hime was soon followed by many different art forms.

It should be stressed that the Edo period marked the origin of Japan's mass media. For the first time Japan had the ability to create media for the masses. Formerly scrolls had been meticulously produced by hand as one-off unique items which were precious and expensive. All of a sudden in the Edo period, thanks to the printing press narratives and also art became cheap and quick to produce. They were designed to be read and thrown away and people did not keep them. They also used these narratives and works of art to sell carbon black inviting people to produce their own artworks.

Kudabe began to appear in the 1820s with these prophetic Yōkai in what were essentially imitations of the story of the Jinja Hemi. Kurabe is a chimera or combination of different monsters from different animals; it has a cat-like body and a human head. Although the story they tell never changes, Kurabe was not very popular. Subsequently however the Tenpo famine (1830-1844) occurred which meant that the Kudan took the form of a cow with a human head relating the same prophecy and the need to share its picture to be healed.

In 1844 the Amabiko appeared with a large head, three legs, and the same story with the same ending: share my picture. None of the details change significantly. However, the previous Amabies were both aquatic and this one is a mountain creature which is more in accordance with the Kudon. So there is a merging of the Kudori story with the mythology of Amabie at this point where its derivative Amabiko still contains the word ocean in the Kanji language.

The Amabiko Nyudo subsequently appeared in 1852 in another kind of merging with an existing Yōkai character. Japanese has several language systems; that of Kanji shows the meaning but not the pronunciation. Another language system known as Katakana shows the pronunciation but not the meaning. The Amabiko of 1844 is written in Kanji in order to have meaning. However, the 1846

Amabie is written in Katakana which tells us that we have no meaning (Davidsson, 2018). At this point prior to COVID-19 it should be taken into account that Amabie stories also helped Japan to personify its trauma through making it into a monster.

COVID-19 began in Japan on 16th January when the first coronavirus case was confirmed. Some days later the Diamond Princess cruise was quarantined in Yokohama Harbour as a plague ship carrying the virus on 3rd February. Ten days later the first coronavirus death occurred in Japan. On 26th February all sports and cultural events were cancelled and schools were closed. The following day an artist named Orochido, who specialises in printed Yōkai scrolls, sent the first Amabie tweet on Twitter. Orochido has been selling different Yōkai scrolls for a number of years as his own artwork. What Orochido really wanted to do was to sell his scroll at a price of ¥1,639. At the time no-one realised how widespread the coronavirus was going to be. The next days the artist Kitano Yōkai posted a full Amabie comic strip to illustrate the old story of 1846 of the light in the ocean. As soon as people began to read this comic strip of 29th February with its historical context they started making their own art. The speed with which Japan responded to the Amabie was impressive. Many people created artworks at home to a high standard as Amabie cookies; all the work was in many different colours despite the fact that earlier Amabie material was in black and white (Figure 11).

Figure 11. The first Amabie

According to Yahoo's metrics, after that first tweet of the cartoon there were 23,000 tweets on the subject of Amabie in the next eleven days. So virtual Japan showed this massive response which was followed by other countries, artists, and researchers beyond Twitter.

Figure 12. The COVID-19 Japanese campaign.

As a follow-up to all these events the Japanese government adopted the Amabie as the official mascot of their COVID campaign (Figure 12) in a bid to convince people to wear masks and use social distancing. All this is conveyed by the Amabie character. Furthermore, movie colouring books were printed and sent out to children as they were home from school. Japan Airlines created an Amabie plane which flew all over Japan to share the image of Amabie with the entire country and sculptures were also created.

EPILOGUE

Decolonisation brought about the emergence of new identity discourses which permeated cultural practices including scientific ones: the question of authenticity, the question of one's own culture, gender inequalities, and the history of racial denigration and slavery play an important part in the narratives of the time. A new form of critique emerges from the idea that the theory which has arisen from European culture cannot account for the diversity and complexity of the culture which is the effect of colonialism. These aspects are brought together under the heading of postcolonial studies. Post-colonialism would unmask these prejudices and show that in fact there is no centre or periphery as culture is always otherness.

Indeed, we can only label them as belonging to a European tradition which shows that culture is diversity. As we have seen the idea of a central and monolithic culture was soon discarded by Western intellectuals and thinkers in favour of an indisputable heterogeneity. Perhaps the originality of postcolonial studies lies in the fact of having supplied these theories with cultural material which is at heart profoundly hybridised. As Spivak (1988) maintains, against the more essentialist positions the idea of a colonial subject cannot be reduced to an idea of origin or belonging. The subject, as an effect of discourse, is the result of a myriad of discourses. It is not therefore possible to think of politics based on immobile fixed identities. According to Spivak there is no place for an individual prior to colonisation which embodies the individual.

Hypermodernity designates a new moment in history marked by anguish and a sense of precariousness. There is no doubt that the 21st century has begun with a major hypermodern crisis. Health, work, and housing, have come to lead the concerns of the people of the West. Despite all this, citizens continue to cherish certain values such as solidarity, the defence of the welfare state, and the right to defend the welfare state and human rights. Virtual space seems to have displaced the real space of the individual; anything quickly becomes obsolete and existence seems to develop in a perpetual "now". Links are fast, volatile, and ephemeral, and this is reflected in life at work, love life, and family life. All this produces in the subject a strong feeling of up-rootedness and disidentification. The family and work signifiers which used to give consistency to the identity of an individual, although they could be experienced as a suffocating yoke, have disappeared. Today one is born in one corner of the world but can live in many other and very distant parts of the world. The individual is offered a multitude of objects of all kinds called to fill this structural void, among which electronics reign supreme. Moreover, culture has become a great dispenser of objects. In these contexts Amabie proves how relevant and important Yōkai still are to the virtual world in that people still connect to them. It adds all kinds of interesting ideas to the concept of Yōkai in terms of belief but also in terms of playfulness and how this fits into popular media and popular culture and people's own creativity. One of the characteristics of these creatures is what can be termed the liminal space or the kind of the unknown which emerges on the Internet.

THE IMAGE OF SCIENCE IN A SAMPLE OBTAINED BY "NATURAL SELECTION": RESULTS FROM A FACEBOOK MARKETING CAMPAIGN

Ana Muñoz van den Eynde

Surveys of public perception of science are the main tool for analysing the relationship between science and society. The origins are public opinion polls and, therefore, they tend to be designed from the perspective of what can be defined as a "sociological paradigm". It is based on two central premises: 1) the questions must be formulated as neutral statements so as not to influence the minds of the respondents and skew their answers, 2) to be valid, the data must come from a representative sample of the population. From a research perspective, it can be said that the surveys thus designed are equivalent to working under ideal and controlled conditions in a laboratory. But research can and should also be done in real or natural conditions. This chapter describes the image of science in a sample obtained under natural conditions through a marketing campaign on Facebook. The results show that despite the fact that in the "traditional" surveys of public perception of science in Spain (for example, the latest Eurobarometer on science and technology) there seems to be 41% of the population very interested in the subject and 45% moderately interested, only 2% (at best) of people contacted via Facebook were interested enough to click on an ad asking them to answer a survey to know their image of science. As a result, we obtained a sample of science "advocates": people who are very interested in it but from a critical perspective: they believe that science and technology bring great benefits, but also risks. On the other hand, in their role as "defenders" they tend to disagree with the public participating in decision-making on scientific and technological issues.

INTRODUCTION

Dating back to the 1980s, the origins of research into the relationship between science and society derive from the "anxious international reactions of institutions, patrons and beneficiaries to emergent public movements that began questioning the radical programs of innovation" which developed as from the end of World War II (Wynne, 2014, p. 61). Until then, society reacted in a clearly positive fashion to all the advances, developments and products that science and technology were able to offer. Hiroshima and Nagasaki, together with the book *The Silent Spring* by Rachel Carson warning about humans' ability to deplete the environment, raised people's awareness about the unwanted consequences of those advances. As a result, society rescinded the blank check of trust given to scientific and technological developments. Thereafter, politically managing the relationship between science and society grew ever more complex, thus giving rise to the need for research into this issue.

Research about the relationship between science and society relies on the premise that it is negatively conditioned by some sort of dysfunction. In this context, public perception surveys of science have become a tool to identify the elements that contribute to suppressing such supposed dysfunction. The information thus provided would need to be translated into a diagnostic assessment of the situation and of the causes of the problem. However, the results obtained to date are inconsistent, and this goal has not been achieved.

There are several reasons behind this inconsistency. On the one hand, the research method has been blamed, providing yet another example of the paradigm war in social research. In this "war", the clearest manifestation arises in the battles between quantitative and qualitative methodologies. In studies on the social perception of science, critics of the quantitative methodology contend that surveys distort the essence of the social perception of science and, therefore, its analysis can only be addressed through qualitative studies (Kallerud & Ramberg, 2002). The problem is that this debate has been dominated by methodological arguments to the detriment of theoretical ones. Nevertheless, in any science, considerations about the method to be used must first take into account the nature of the phenomenon to be investigated. Decisions about the method should be subsequent and based on these considerations (Kelle, 2001). Therefore, research difficulties in the field would not be caused by the method, but by the lack of an adequate research design and a theoretical framework in which the concepts to be measured and the procedure to do so are defined. In other words, the problem is not in the method but in how it is used (Muñoz van den Eynde, 2014).

Three main conclusions can be drawn from data taken from surveys on the public perception of science. First, surveys are sensitive to changes in perception due to the influence of the social backdrop and hence they can provide a fitting description of reality (Muñoz van den Eynde, 2013; Muñoz van den Eynde & Luján, 2014). Second, there is little variability in the responses and so it is common to find floor and ceiling effects; therefore, surveys carried out to date have shown scant discrimination capacity. Third, surveys usually include a series of questions about interest, opinion, public policy or attitude towards scientists, but the analysis about the association between all these questions has shown the relationship to be very weak or nonexistent (Muñoz van den Eynde, 2013; Muñoz van den Eynde & Luján, 2014).

SURVEYS AND COGNITIVE PROCESSING

Like all opinion polls, public perception surveys of science are based on the assumption that human beings are rational and provide all their answers and judgments after thinking about them thoroughly and in detail. A survey question is a kind of instruction in which respondents are asked to do whatever mental work is necessary to provide an answer (Conrad, Blair & Tracy, 1999), but there is evidence that respondents rely on heuristic strategies when answering surveys. They draw inferences from the structure or order of the response options, have some difficulties with numerical categories and rating scales and thus use a number of strategies to simplify the task of mapping their judgments onto an acceptable answer. Additionally, despite respondents' tendency to distribute their responses among all the response categories, they show some reluctance to use the extreme categories or endpoints of the response scale, i.e. they tend to cluster their opinions around a central response option (Tourangeau et al., 2000).

The Model of the Response Process (Tourangeau, 1984) posits that respondents need to accomplish four tasks to answer survey questions: (a) comprehend the question, (b) retrieve relevant information from long-term memory, (c) make a judgment based upon the retrieved information and (d) fit their answer among the options provided by survey designer. Optimizing is the cognitive process entailed in answering a survey question by performing the four tasks thoroughly (Krosnick, 1991). On the contrary, satisficing is a strategy developed to minimize the cost (response burden), which provides a result of lower quality (Truebner, 2021).

The notion of satisficing was first developed by Herbert Simon (Simon, 1956). To understand Simon's rationality, we need to consider both the limited computing capacity of organisms and the environment in which they exist. As a result of the limits on computational capacity, considering that people will optimise when answering a survey is not a realistic perspective (Simon, 1955).

The assumption that agents are rational is central to much theory in the social sciences (Kahneman, 1994). Yet, when the rational agent model has been tested in the laboratory and the real world, even in relatively simple situations, the behaviour of subjects has tended to widely depart from the predictions derived from the model (Simon, 1978). Contrary to the model's assumptions, humans' basic tendency is to default to processing mechanisms of low computational expense (Stanovich, 2020). Thus considered, satisficing can be conceived as the default strategy respondents ground themselves on when answering a survey; they look for cues in the questions that will help them to offer a sufficient answer. Accordingly, questionnaire design is essential to guarantee data quality.

SURVEY DESIGN AND SAMPLING

Sampling in public opinion surveys is aimed at obtaining probabilistic samples. This strategy makes it possible to generalize the data from the sample to the reference population, meaning that what has been found in the sample is probably true when applied to the general population. However, the focus on representative samples of the population is costly in financial and logistical terms and in terms of the resources needed to progress in the research. In addition, to ensure the response rate, questionnaires have to be accessible and easy to answer, which limits content validity. Furthermore, representativeness depends on the respondents being selected randomly and so when people refuse to participate in a survey, randomization becomes unattainable. Problems associated with nonresponse have been an object of study since the mid-1900s as a result of their detrimental effect on survey quality (Shoemaker et al., 2002). Nonresponse includes noncontacts (the impossibility to access the selected target) and refusal rates (people declining to take part in the study). Declining response rates, mainly of noncontacts, has been internationally identified. Since the emergence of the COVID-19 pandemic, the problem has been aggravated, rendering home interviews nearly impossible.

Using surveys as research tools is also grounded on the assumption that people have an opinion on all issues of interest to social researchers and are more than willing to cooperate with the interviewer at a mere knock on the door. As mentioned, this willingness cannot be taken for granted. Additionally, when interviewers phone or knock on the door asking for respondents' cooperation, they are interfering with their routines. This is bothersome, making it very unlikely that those who agree to answer the survey will put much cognitive effort into the task. As a survey mode, the Internet has become increasingly common in survey research, despite the issue of invalid responses being considered problematic. While not specific to web-based surveys, they are considered one drawback of web-based surveys. A web page "may give respondents a sense of reduced accountability" in comparison to a printed questionnaire and so they are more likely to occur on the Internet (Leiner, 2019). However, they are very useful because respondents can decide when they answer the questions. In this connection, response behaviour in web-based surveys was found to be similar to classic pen-and-paper mail surveys (Leiner, 2019).

THE PIKA SURVEY

The PIKA survey has been designed to measure four elements of the image of science (see The image of science): Perception (opinions and attitudes), Interest, Knowledge and Action (the willingness to put science into practice).

When designing a questionnaire, several issues must be considered that are not usually sufficiently taken into account in the design of surveys on the social perception of science. Before thinking about how to measure something it is important to be clear about what is to be measured and then think about the best way to do it. To do this, we cannot ignore how information processing strategies influence the responses of potential participants in the study. Each person is constantly subjected to vast amounts of highly varied information. Cognition is the set of activities through which this information is processed. This process does not wholly depend on objective characteristics, but is rather the mental reconstruction of what is real carried out by individuals based on their past experience, their needs, desires and intentions. In real life, people do not actually deal with neutral and wholly objective information and sentences. For a questionnaire to have external validity (to be able to explain what people think or do in their daily lives), its statements must be closely tailored to what people will face in real conditions. Additionally, in designing the questionnaire it has been assumed that the only way to try to avoid the problems associated with cognitive processing is by carefully designing the questions to be asked in an attempt to ensure that respondents answer what is being asked. The result is a questionnaire that is time- and effort-consuming (Muñoz van den Eynde et al., 2017).

In the 3.0 version of the PIKA survey we opted for a unipolar scale with six labelled response options. In the two previous versions we had selected a four-option scale. Designing this version, we decided to follow the recommendation found in the literature about including a higher number of options to offer respondents the possibility of bringing more accurate opinions. This was also the recommendation of a sample of students at the University of Oviedo after accessing the pilot version of the survey with only four response options.

The questionnaire (available in the Annex) is organized into three sections. Section 1 makes up the main body and includes 29 questions on perception, interest, knowledge and action. Section 2 is designed to analyse certain hypotheses about the factors that influence the image of science. It includes four criteria questions about stances regarding science, interest, perceived knowledge and willingness to engage in science policy decisions. It also includes three questions measuring verbal reasoning and another three that are adaptations to the items of the Cognitive Reflection Test (CRT) designed in 2005 by the psychologist Shane Frederick to measure people's tendency to override an incorrect "gut" response and engage in further reflection to find a correct answer. The test has a moderate positive correlation with measures of intelligence, and it correlates highly with various measures of mental heuristics and a question about critical thinking. Section 3 includes sociodemographic variables: age, gender, level of studies and the subject studied (general training programs; natural sciences; engineering and technology; medicine and health sciences; social sciences, business/law; teacher training and educational sciences; or languages, arts and the humanities).

One last issue to consider is how to get the survey to the participants. The fact that the results of public opinion surveys can be significantly affected by the way in which questions are worded, the form in which they are presented, and the order or context in which they are asked is well known. Nevertheless, their influence may be affected by psychological variables that probably covariate with the mode of data collection (Schwarz et al., 1991). To administer the PIKA survey we used a computer tool that provides access to the survey through the Internet, which has been found to be a useful route of administration that allows for a good response rate (Heerwegh & Loosveldt, 2008). Also, vision is the sense that most affects our mind, and much of our thinking is visual, such that more than 50% of the human cerebral cortex is dedicated to this sense (Viosca, 2018). Therefore, apart from the advantage that the Internet offers participants in the possibility to choose when to respond, we have assumed that respondents will be more likely to invest sufficient cognitive effort in answering the questionnaire if they read the questions (visual stimuli) instead of hearing them (auditory stimuli). Further, it can be said that obtaining a representative sample of the population would be equivalent to establishing the ideal conditions for a controlled experiment. As a result, a perfect sample is obtained in sociodemographic terms. Spontaneity may then be lost. How do ordinary people react when they receive an invitation to participate in such research? How many people have enough interest in science to get involved? These are questions that we think can be best answered through an advertising campaign. From our perspective, this strategy provides information about the image of science in real conditions. Therefore, the version 3.0 of the PIKA survey was distributed online through a marketing campaign on Facebook. People were presented two ads that included the link to the survey. One ad made reference to the need of sharing their opinion about science: "Your view on science matters. Questionnaire PICA 2021. Take part!" The other tried to represent the perspective of those who feel concerned about the impact of science on society: "If you are concerned about how science influences society, take part! Questionnaire PICA 2021".

FIELD WORK, SAMPLE SIZE, MISSING VALUES AND REACTION TO THE ADS

The Facebook campaign targeted people 18 years of age and older, without selecting profiles, i.e. without segmenting. The ads reached 1,087,748 Facebook users. There were 22,246 (2%) clicks, meaning only 2% of those who received the ad were sufficiently interested or curious to interact with it. Or less, as there might have been stray clicks. This result can be interpreted as a lack of real interest in science or as a negative attitude towards surveys, but it could also be a reflection that people do not have a defined opinion or image of science. It is probably a combination of all three. Anyway, if the third hypothesis turns out to be true, it would be interesting to ask ourselves what we are measuring when we ask people their opinion of science under ideal or controlled conditions. Lastly, among the more than 22,000 people who clicked on the ad, 1,441 interacted with the survey (6.47% of those who clicked the ad, 0.13% of those who received it).

The fieldwork was carried out between 22 June and 26 August 2021, when the budget for the advertising campaign ran out. Overall, 508 people reached the final question. The response rate among those who entered the survey is 35.25%. Focusing on those who clicked the ad, the response rate is 2.28%. With respect to those who received the ad, the response rate is a negligible 0.05%. The final sample consisted of 581 people who answered at least 90% of the questions. There were 8.1% of respondents who dropped out after completing the main section (n = 47), 1.7% (n = 10) after completing the criterion questions, another 1.7% (n = 10) after completing the verbal reasoning questions, 1.4% (n = 8) after completing the CRT questions, 1% (n = 6) answered the critical thinking question once and another 1% (n = 6) left the questions on sociodemographic variables unfinished. In the end, 85% answered questions from all sections of the survey. There were 177 people (30.5%) who answered every question.

AGE *	SCOPE	CLICKS	ANSWERS	CLICK BY ANSERW
> 65	27.7%(301,825)	49.1%(10,916)	11.4%(57)	192
55-64	26.1%(284,417)	30.7%(6.837)	24.6%(123)	56
45-54	12.6%(137,216)	9.2%(2,045)	19%(95)	22
35-44	10.3%(111,874)	4.6%(1.012)	17.4%(87)	12
25-34	11%(132,608)	3.4%(762)	12.6%(63)	12
18-24	10.9%(132,608)	3%(674)	14.8%(74)	9
TOTAL	100%(1,087,748)	100%(22,246)	100%(499*)	45

Table 10. Response profile by age

Table 10 provides two relevant pieces of information. First, there are no marked differences in the response rate between the different age groups, except for the group between 55 and 64 years old, which represents nearly a quarter of the sample. Second, the clicks needed for each answer increase by age, especially in the oldest groups.

AGE	SCOPE	CLICKS	ANSWERS	CLICK BY ANSERW
Unknown	0.6%(6,658)	0.4%(89)	14.5%(84)	1
Male	55.4%(603,137)	53.3%(11,857)	57.7%(335)	36
Female	43.9%(477,953)	46.4%(10,300)	27.9%(162)	64
TOTAL	100%(1,087,748)	100%(22,246)	100%(581)	39

Table 11. Response profile by gender

Table 11 shows that there are significantly more responses from males than from females, and also that they need less clicks to provide an answer.

DEVICE	SCOPE	CLICKS
Android Smartphone	79.1%(860,931)	85.2%(18,952)
Android Tablet	5.7%(61,952)	7.6%(1,685)
iPhone	11.2%(121,344)	3.2%(713)
Computer	4.7%(50,688)	2.3%(515)
iPad	1.4%(15,360)	1.5%(333)
Other	0.2%(2,304)	0.2%(45)
TOTAL	100%(1,087,748)	100%(22,246)

Table 12. Response profile by device

Table 12 indicates that nearly all respondents took the survey by phone (Android and iPhone for almost 90% of responses). Only 4.7% of those surveyed used a computer. This finding could explain the low response rate, as a complex and extensive survey seems difficult to complete with a small device.

Initially, responses to Ads 1 and 2 were included in the same database, but they were split out on 12 July. There were 52.3% respondents who accessed the survey through Ad 1 (n = 304), 9.6% through Ad 2 (n = 56) and 38% answered before the database was split out (n = 221). There were more than five times more people who accessed the survey through Ad 1 than through Ad 2.

There were no statistical differences between males and females regarding the ad through which they accessed the survey (Chi-square = 4.73, $p > 0.05$). There are significant, albeit weak, differences due to age (Chi-square = 41.5, $p < 0.01$, Cramer's V = 0.19). The adjusted standardized residuals (ASR) for those aged 18 to 25 in Ad 2 is 5.43 (the significant value is 2). It must be taken into account that the mixed group collects the initial responses. Therefore, young people mostly responded once the two ads were separated. Also, comparatively they opted to a greater extent for Ad 2 (38 responded to Ad 1, 20 to Ad 2 and 16 to the combination of both).

SOURCES TO BE INFORMED ABOUT SCIENCE AND TECHNOLOGY

Overall, 7.2% (42 people) did not answer this question. The minimum value is "I don't usually look for information", which is not a "No" in the strict sense. It is therefore possible that they are people who do not look for information at all. Another 1.5% (9 people) say they do not usually look for information, 30% mentioned books or other publications (n = 174) and 50% mentioned the Internet (n = 290). Only the first answer is analysed

When asked where they look for information on the Internet, 18.9% (n = 110) did not answer. This figure includes the 51 people who do not seek information, those who did not mentioned the Internet and those who decided not to answer this question. Most of the people who get information online do so through search engines (32.7%, n = 168), while 25.8% (n = 150) do so through institutional websites. The other categories are mentioned to a lesser degree: 9% (n = 52) do so through social media and 4.3% (n = 25) through traditional media.

When asked, “Which of the following sentences best reflects your opinion on the information available on the Internet?”, 2.1% (n = 12) consider that “in general you can't trust the Internet because almost all the information on it is misleading”, 10.3% (n = 60) think that “on the Internet there is information of good quality but most of it is misleading”, 2.9% (17) find that “some of the information on the Internet is misleading although most of it is of good quality” and 82.1% (477) believe that “on the Internet there is both good quality information and misleading information; the important thing is to know where to look”. Only 2.6% (n = 15) believe that “in general you can trust the Internet because most of the information on it is of good quality”.

There are no differences in the responses due to the ad clicked or gender, but there is a difference due to age (Chi-square = 46.93, $p < 0.01$, Cramer's V = 0.14). Those aged 26 to 35 stand out because they consider that there is good quality information on the Internet, even though most of it is misleading (ASR= 4.6). They also stand out in affirming to a much lesser extent that there is good quality and misleading information and the important thing is to know how to search well (ASR = -3). Those aged 65 and older stand out for considering that in general you can trust the Internet because the information available is of good quality (ASR = 4).

When asked to what extent they trust the information that can be obtained on social media, 9.6% (n = 56) do not trust the information on social media at all, 30% (n = 174) trust it very little, 18.4% (n = 107) barely trust it at all, 31% (n = 179) trust it to some extent, 10.2% (n = 599) trust it quite a lot and 1% (n = 6) trust it a lot.

Trust in social media does not depend on age or gender. There are also no differences relating to the ad through which respondents accessed the survey. In turn, there are statistically significant differences depending on the source of information they use on the Internet (Chi-square = 65.38, $p < 0.01$, Cramer's V = 0.23). Those who use social media trust somewhat (ASR = 2.7) or a lot (ASR = 5). There are no differences between those who use search engines. Those who use institutional websites trust nothing (ASR = 3.8) or very little (ASR = 2.8).

ACTION

ACTIONS RELATED TO THE USE OF INFORMATION

By far the most frequent action is to search for information on the Internet to correctly understand news or information about science and technology. In fact, 75% of the people surveyed perform this action frequently or widely. The other actions are rarely performed (Table 13).

ACTIVITIES IN WHICH RESPONDENTS WOULD TAKE AN ACTIVE PART IF THEY RECEIVED AN INVITATION TO DO SO

Respondents seem to be willing to participate in all the activities they are questioned about. The fact that they are especially willing to take active part in an inquiry to decide which science project should receive public financing is a clear indication that the sample is biased and respondents are highly science “advocates”. Conversely, the activities less attractive for the sample are “signing a petition to request the consultation of citizens in decisions on science and technology which directly affect them” and “watching a show of monologues of science” (Table 14).

ITEMS	VERY OFTEN	OFTEN	FROM TIME TO TIME	NOT OFTEN	HARDLY EVER	NEVER	DON'T ANSWER
Requesting or providing technical, scientific, or academic information in forums, chats, social networks, and other similar tools	11(64)	23.1(134)	23.4(136)	13.8(80)	16(93)	12.6(73)	0.2 (1)
Making searches on the Internet in order to understand news about or information on science and technology correctly	41.3(240)	40.8(237)	12.7(74)	2.8(16)	1.2(7)	1(6)	0.2(1)
Retweeting or sharing on other social networks news about or information on science and technology	12.7(74)	20.3(118)	26(151)	12.6(73)	14.8(86)	13.3(77)	0.3(2)
Asking someone for help (family, friends, teachers…) so as to better understand news about or information on science and technology	5.9(34)	16.5(96)	27(157)	17.7(103)	19.1(111)	13.3(77)	0.5(3)
Creating specific contents for blogs or websites of a technical, scientific, or academic nature	2.4(14)	6.7(39)	12.9(75)	10.8(63)	15.8(92)	50.3(292)	1(6)
Giving your opinion in a discussion on a scientific matter on a social network or a forum on the Internet	0.5(3)	6.4(37)	16.5(96)	22.7(132)	13.1(76)	20.8(121)	20(116)

Table 13. Frequency distribution: actions related to the use of information

ITEMS	VERY OFTEN	OFTEN	FROM TIME TO TIME	NOT OFTEN	HARDLY EVER	NEVER	DON'T ANSWER
Requesting or providing technical, scientific, or academic information in forums, chats, social networks, and other similar tools	11(64)	23.1(134)	23.4(136)	13.8(80)	16(93)	12.6(73)	0.2 (1)
Making searches on the Internet in order to understand news about or information on science and technology correctly	41.3(240)	40.8(237)	12.7(74)	2.8(16)	1.2(7)	1(6)	0.2(1)
Retweeting or sharing on other social networks news about or information on science and technology	12.7(74)	20.3(118)	26(151)	12.6(73)	14.8(86)	13.3(77)	0.3(2)
Asking someone for help (family, friends, teachers…) so as to better understand news about or information on science and technology	5.9(34)	16.5(96)	27(157)	17.7(103)	19.1(111)	13.3(77)	0.5(3)
Creating specific contents for blogs or websites of a technical, scientific, or academic nature	2.4(14)	6.7(39)	12.9(75)	10.8(63)	15.8(92)	50.3(292)	1(6)
Giving your opinion in a discussion on a scientific matter on a social network or a forum on the Internet	0.5(3)	6.4(37)	16.5(96)	22.7(132)	13.1(76)	20.8(121)	20(116)

The results indicate percentage and size: %(n)

Table 14. Frequency distribution: activities in which respondents would take part if they receive an invitation to do so

BEHAVIOURS IN WHICH PEOPLE MAY ENGAGE IN DURING THEIR DAILY LIFE

ITEMS	NEVER	HARDLY EVER	NOT OFTEN	FROM TIME TO TIME	OFTEN	VERY OFTEN	DON'T ANSWER
Talking of science with your friends when an important discovery, such as the Higgs boson or proof that gravitational waves exist, comes up on the news	2.9(17)	7.6(44)	9.1(53)	31.2(181)	28.7(167)	20.5(119)	0
Looking for information to find out what to do when a news item related to science and technology which affects you comes up (for example, COVID-19 treatment and vaccination)	1.2(7)	1.2(7)	1.2(7)	12.0(70)	41.8(243)	42.3(246)	0.2(1)
Taking part in collecting signatures or in demonstrations on subjects related to science and technology (for example nuclear power, biotechnology, the environment…)	19.1(111)	17.9(104)	16(93)	26.9(156)	13.8(80)	6.2(36)	0.2(1)
Taking part in lectures or other popular science activities (Science Week, scientific monologues, museums or exhibitions…)	13.1(76)	15(87)	18.1(105)	27.9(162)	18.8(109)	7.1(41)	0.2(1)
Consulting different sources to test the information you receive	0.7(4)	0.9(5)	1.9(11)	11.2(65)	38.6(224)	46.6(271)	0.2(1)
Resending automatically to your acquaintances and relatives the information you receive by other channels (e-mail, Whatsapp, etc.)	28.7(167)	25.5(148)	16.5(96)	17.6(102)	7.9(46)	3.4(20)	0.3(2)

Table 15. Frequency distribution: behaviours in which people may engage in during their daily life

Table 15 indicates that the people who have responded to the survey frequently look for information to make better decisions and consult different sources of information to verify the information they receive. Further, hey do not usually automatically forward the information they receive to their acquaintances and relatives. It can thus be said that the sample mainly comprises people with a scientific attitude.

KNOWLEDGE

The PIKA Survey includes six questions to measure people's knowledge about meteoroids, energy, cloning, particles, genetics and the number pi. Each question has three items and each item has three options. Respondents have to select the option which they consider is correct.

ITEMS	DON'T ANSWER	OPTION 1	OPTION 2	OPTION 3
P5_a	0.9 (5)	0.5(3)	94.3(548)	4.3(25)
P5_b	1.0(6)	6.4(37)	1.0(6)	91.6(532)
P5_c	1.7(10)	7.4(43)	75.6(439)	15.3(89)
P6_a	0.9(5)	0.5(3)	13.3(77)	85.4(496)
P6_b	1.2(7)	24.4(142)	72.1(419)	2.2(13)
P6_c	0.3(2)	3.8(22)	15(87)	80.9(470)
P7_a	1.2(7)	36.5(212)	59.6(346)	2.8(16)
P7_b	0.5(3)	3.3(19)	88.0(511)	8.3(48)
P7_c	0.9(5)	7.9(46)	90.4(525)	0.9(5)
P8_a	0.9(5)	88(511)	1.0(6)	10.2(59)
P8_b	0.7(4)	1.4(8)	97.1(564)	0.9(5)
P8_c	1.4(8)	7.1(41)	90.4(525)	1.2(7)
P9_a	0.5(3)	0.3(2)	2.8(16)	96.4(560)
P9_b	1.5(9)	24.1(140)	29.3(170)	45.1(262)
P9_c	1.9(11)	18.4(107)	70.1(407)	9.6(56)
P10_a	0.5(3)	1.2(7)	97.8(568)	0.5(3)
P10_b	3.1(18)	18.9(110)	4.3(25)	73.7(428)
P10_c	0.7(4)	4.8(28)	3.4(20)	91(529)

Table 16. Frequency distribution: questions measuring knowledge (correct answer in bold)

The percentage of people who do not answer an item tends to increase in proportion to difficulty (i.e. there is a lower percentage of correct answers). The most difficult is item 9b, which ask about biotechnology. Question 9c was difficult probably because it is more controversial, since it relates to the social debate on genetically modified food. In fact, in the comments generated by the survey, Facebook users specifically criticized this question, implying that it entailed manipulation. Question 10b, which involves thinking about what pi means rather than identifying stored knowledge, also proved difficult.

PERCEPTION

USEFULNESS OF SCIENTIFIC KNOWLEDGE

ITEMS	NOT AT ALL	VERY LITTLE	LITTLE	TO SOME EXTENT	QUITE A LOT	A LOT	DON'T ANSWER
In understanding the world	1(6)	1.2(7)	0.9(5)	6.9(40)	22.7(132)	67.3(391)	0
In healthcare and the prevention of diseases	0.9(5)	0.7(4)	0.7(4)	6(35)	19.1(111)	72.5(421)	0.2(1)
In caring for the environment	1.2(7)	1(6)	1.5(9)	5.7(33)	19.8(115)	70.7(411)	0
When making decisions as a consumer	1(6)	2.1(12)	2.1(12)	11.7(68)	31.5(183)	51.5(299)	0.2(1)
In your profession or job	1.9(11)	3.1(18)	4.8(28)	14.1(82)	20.5(119)	55.6(323)	0

The results indicate percentage and size: %(n)

Table 17. Frequency distribution, mean and standard deviation: usefulness of scientific knowledge

Table 17 indicates that people tend to associate the usefulness of scientific knowledge with its application to solving problems (healthcare and care for the environment) to a greater extent than to more abstract questions. The topic in which the highest option is selected less frequently is decision making as a consumer. Focusing on the average, a very high value is obtained in the five topics included (greater than 5). The highest average, nearly 5.6, is related to healthcare and disease prevention. The lowest value is related to profession or job.

FUTURE BENEFITS AND RISKS OF SCIENCE AND TECHNOLOGY

OPTIONS	BENEFITS OF THE DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN THE NEXT 20 YEARS	RISKS OF THE DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN THE NEXT 20 YEARS
Many	66.3(385)	7.9(46)
Quite a few	22.4(130)	15.5(90)
Some	7.9(46)	48.5(282)
Few	1.2(7)	12.9(75)
Very few	0.3(2)	13.1(76)
None	1.7(10)	1.9(11)
Don't answer	0.2(1)	0(1)

Table 18. Frequency distribution: future benefits and risks of science and technology

Respondents mainly believe that science and technology will provide multiple benefits in the future, but they also consider that they will entail risks, which indicates that respondents have a positive attitude towards science and technology, but with a critical perspective. In other words, they take an approach far removed from the *legend* of science and from the idea that science and technology are perfect and can sort out any problem without undesired consequences.

SCIENCE FEATURES

In this section the objective is to identify what respondents think science is. Therefore, they have to say the extent to which they associate science with a set of nine positive and negative terms (risk, boredom, usefulness, safety, difficulty, mistrust, benefit, uncertainty and knowledge) on a scale from 1 to 6. Nonresponses are assigned the value 0. If the lack of response is considered to be an indication of difficulty, it can be said that people have some problems in thinking about science in terms of security, difficulty and mistrust.

FEATURES	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
Risk	1	6	2.8	1.5
Boredom	1	6	1.6	1.0
Usefulness	1	6	5.6	0.8
Safety	0	6	4.7	1.2
Difficulty	0	6	4.6	1.3
Mistrust	0	6	2.1	1.3
Benefit	1	6	5.4	1.0
Uncertainty	1	6	3.6	1.5
Knowledge	1	6	5.6	0.9

Table 19. Descriptive statistics: science features

Looking at Table 19, and considering nonresponse as an indication of difficulty, it can be said that people have some problems thinking about science in terms of security, difficulty and mistrust. However, results show that respondents clearly identify science both with knowledge and utility and do not associate it with boredom or mistrust. Also, respondents tend to associate it more with uncertainty than with risk.

CONCERN ABOUT SCIENCE

Surveys on the public perception of science tend to focus on respondents' opinions. With this question, the PIKA survey attempts to identify respondents' concern for certain characteristics of science rather than their opinion. The response scale has six options that range from a lot to not at all. Therefore, in this question the order is reversed: lower values indicate higher concern.

There are six items with a minimum value of 0, i.e. there are statements which some participants did not answer to. In all the statements there are participants who do not feel concern about the related content (thus selecting option 6). Respondents are especially concerned about the research budget in Spain being lower in comparison with other European countries. The least concerning issues are: "News on science says one thing one day and the opposite the next" and "Most of the time scientists disagree with each other". However, the values of the standard deviations are higher compared to other questions, thus showing greater heterogeneity in the responses. This is probably one of the issues where sampling bias is most evident.

FEATURES	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
Uncertainty is a characteristic of science	1	6	3.1	1.5
When decisions are made on matters related to science which have repercussions for all of us, citizens are not asked for their point of view	1	6	3,00	1.5
We depend more and more on science and technology in our daily lives	1	6	2.3	1.5
News on science says one thing one day and the opposite the next	0	6	4,00	1.4
Science and technology applications are available for anyone to use whatever their intention	0	6	3.1	1.4
Science and technology are so complicated that few people can really understand them	0	6	3.4	1.4
Scientific and technological progress occurs so fast that the authorities cannot control it properly	0	6	3.1	1.4
Science is too closely related to politics	1	6	2.9	1.4
Scientific and technological development may have unexpected side effects	0	6	2.9	1.3
Most of the time scientists disagree with each other	0	6	3.7	1.4
The research budget in Spain is lower than that of other European countries	1	6	1.44	0.9

Table 20. Descriptive statistics: concern about science

PERCEPTION ABOUT GENETICALLY MODIFIED FOODS

Respondents do not seem to consider genetically modified foods very dangerous and heavily support research in this field (Table 21). At the same time, they believe that this research must be controlled. They find the potential misuse of this food to be more worrisome than its undesired effects. They also tend to consider them useful and beneficial to society. Nevertheless, there are also people that have a more negative perspective about them.

PERCEPTION ABOUT CLONING

Respondents largely agree both that there must be research into cloning and that research should be controlled (Table 22). They also agree to some extent that cloning is dangerous and are somewhat concerned about unwanted effects, but concern mainly relates to the use that can be made of this technology. It is considered useful and its benefit for society is identified but with certain reservations.

ITEMS	NOT AT ALL	VERY LITTLE	LITTLE	TO SOME EXTENT	QUITE A LOT	A LOT	DON'T ANSWER
Transgenic foods are dangerous	23.6(137)	20.7(120)	18.8(109)	21(122)	12(70)	4(23)	0
Transgenic foods are useful	3.3(19)	4(23)	6.7(39)	19.8(115)	38.9(226)	27.4(159)	0
There must be research into transgenic foods	3.4(20)	1.9(11)	2.4(14)	8.3(48)	31.8(185)	52.2(303)	0
I am worried about the undesired effects of transgenic foods	12(70)	14.3(83)	13.4(78)	20.7(120)	23.8(138)	15.8(92)	0
I am worried about the use which may be made of transgenic foods	5.3(31)	6.7(39)	9.3(54)	22.5(131)	28.9(168)	27.2(158)	0
Transgenic foods are beneficial to society	5.3(31)	5.3(31)	7.9(46)	24.1(140)	35.8(208)	21.3(124)	0.2(1)
Research into transgenic foods must be controlled	3.3(19)	3.8(22)	4(23)	15.3(89)	35.3(205)	38.4(223)	0

The results indicate percentage and size: %(n)

Table 21. Frequency distribution: perception about genetically modified foods

ITEMS	NOT AT ALL	VERY LITTLE	LITTLE	TO SOME EXTENT	QUITE A LOT	A LOT	DON'T ANSWER
Cloning is dangerous	5(29)	14.6(85)	10.2(59)	21.3(124)	27.5(160)	21.2(123)	0.2(1)
Cloning is useful	2.6(15)	2.8(16)	3.8(22)	13.3(77)	33.9(197)	43.5(253)	0.2(1)
There must be research into cloning	3.1(18)	2.1(12)	2.6(15)	8.1(47)	27.2(158)	57(331)	0
I am worried about the undesired effects of cloning	2.1(12)	6.9(40)	7.2(42)	17.7(103)	24.1(140)	42(244)	0
I am worried about the use which may be made of cloning	2.9(17)	5.2(30)	7.6(44)	13.9(81)	26.3(153)	44.1(256)	0
Cloning is beneficial to society	4.3(25)	4.5(26)	4.1(24)	22.2(129)	31.8(185)	33(192)	0
Research into cloning must be controlled	2.4(14)	2.9(17)	5.9(34)	12.4(72)	25.5(148)	50.9(296)	0

The results indicate percentage and size: %(n)

Table 22. Frequency distribution: perception about cloning

PERCEPTION ABOUT NUCLEAR ENERGY

Again, respondents agree that research into nuclear energy must be conducted but controlled. Yet, they are concerned to the same extent about the undesired effects of nuclear energy and the use which can be made of it. They consider nuclear energy to be less dangerous than it is beneficial to society (Table 23).

PERCEPTION ABOUT ARTIFICIAL INTELLIGENCE

This technology is found to be dangerous to a lesser extent than the foregoing item. Therefore, as regards usefulness, 87% agree (a lot or quite a lot), and another 80% find it beneficial for society. There are 90% who agree that research must be conducted into artificial intelligence (Table 24).

PERCEPTION ABOUT STEM CELL RESEARCH

Stem cell research is clearly the applied science modality respondents find least dangerous and most useful and beneficial. As a result, they are not very worried about the use which may be made of stem cell research or the undesired side effects. There is near unanimity that there must be research into it, and the percentage of respondents that agree (quite a lot or a lot) that research must be controlled is lower than in the other applications (Table 25).

PERCEPTION ABOUT SCIENCE AT THE SERVICE OF POLITICS

This is a very interesting question included for the first time in the PIKA questionnaire. When the wording of similar questions is neutral and polite in a sense, the respondent's reaction to the statement is "soft." However, when deniers use science as a political "weapon," there are no polite references to it. As such, we deliberately decided to refer to science for politics in a non-neutral way. However, in the introductory text of the question we include an explanation of what was meant by "science in the service of politics".

Table 26 does not show the existence of a negative attitude towards science as a tool for politics. However, the results also show there is no positive attitude. For 44% of respondents, science at the service of politics is beneficial (quite a lot and a lot) to society, but also 25% think that is only slightly or not beneficial at all (quite a lot or a lot). Almost 40% consider science at the service of politics to be dangerous (quite a lot and a lot), and 28.8% totally disagree that there must be research into this topic.

THE FUNCTIONS OF SCIENCE

Science is primarily identified with obtaining knowledge and, secondarily, with solving problems. It is least associated with guiding political decisions. Here, we again see the reluctance of respondents to associate science with politics. Identification with obtaining economic benefits is also high. Therefore, we see how the three dimensions of science proposed by Ziman (1998) are present: academic science (knowledge), industrial science (economic benefit) and instrumental science (solving problems and relationship with politics) (Table 27).

ITEMS	NOT AT ALL	VERY LITTLE	LITTLE	TO SOME EXTENT	QUITE A LOT	A LOT	DON'T ANSWER
Nuclear energy is dangerous	5(29)	14.6(85)	10.2(59)	21.3(124)	27.5(160)	21.2(123)	0.2(1)
Nuclear energy is useful	2.6(15)	2.8(16)	3.8(22)	13.3(77)	33.9(197)	43.5(253)	0.2(1)
There must be research into nuclear energy	3.1(18)	2.1(12)	2.6(15)	8.1(47)	27.2(158)	57(331)	0
I am worried about the undesired effects of nuclear energy	2.1(12)	6.9(40)	7.2(42)	17.7(103)	24.1(140)	42(244)	0
I am worried about the use which may be made of nuclear energy	2.9(17)	5.2(30)	7.6(44)	13.9(81)	26.3(153)	44.1(256)	0
Nuclear energy is beneficial to society	4.3(25)	4.5(26)	4.1(24)	22.2(129)	31.8(185)	33(192)	0
Research into nuclear energy must be controlled	2.4(14)	2.9(17)	5.9(34)	12.4(72)	25.5(148)	50.9(296)	0

The results indicate percentage and size: %(n)

Table 23. Frequency distribution: perception about nuclear energy

ITEMS	NOT AT ALL	VERY LITTLE	LITTLE	TO SOME EXTENT	QUITE A LOT	A LOT	DON'T ANSWER
Artificial intelligence is dangerous	14.1(82)	17.6(102)	16.4(95)	28.6(166)	15(87)	8.1(47)	0.3(2)
Artificial intelligence is useful	1.7(10)	0.7(4)	2.1(12)	8.6(50)	35.5(206)	51.5(299)	0
There must be research into artificial intelligence	1.4(8(	0.7(4)	1.5(9)	7.1(41)	23.8(138)	65.6(381)	0
I am worried about the undesired effects of artificial intelligence	5.9(34)	10.7(62)	10.2(59)	23.6(137)	22.4(130)	27.4(159)	0
I am worried about the use which may be made of artificial intelligence	2.6(15)	4.1(24)	5.9(34)	17(99)	31(180)	39.4(229)	0
Artificial intelligence is beneficial to society	1.9(11)	1(6)	3.6(21)	13.8(80)	38.2(222)	41.5(241)	0
Research into artificial intelligence must be controlled	2.8(16)	4.8(28)	6(35)	12.6(73)	26.7(155)	46.8(272)	0.3(2)

The results indicate percentage and size: %(n)

Table 24. Frequency distribution: perception about artificial intelligence

ITEMS	NOT AT ALL	VERY LITTLE	LITTLE	TO SOME EXTENT	QUITE A LOT	A LOT	DON'T ANSWER
Stem cell research is dangerous	40.3(234)	25(145)	17.7(103)	12(70)	2.4(14)	2.2(13)	0.3(2)
Stem cell research is useful	0.3(2)	0.3(2)	1.4(8)	3.8(22)	21.3(124)	72.6(422)	0.2(1)
There must be research into stem cell research	1(6)	0.2(1)	1(6)	4.5(26)	15.8(92)	77.3(449)	0.2(1)
I am worried about the undesired effects of stem cell research	15.7(91)	25.3(147)	18.9(110)	20.5(119)	10.2(59)	9.3(54)	0.2(1)
I am worried about the use which may be made of stem cell research	10.8(63)	20.1(117)	15.3(89)	21.3(124)	14.6(85)	17.4(101)	0.3(2)
Stem cell research is beneficial to society	0.9(5)	0.5(3)	0.7(4)	5.9(34)	24.6(143)	67.3(391)	0.2(1)
Research into stem cell research must be controlled	4.5(26)	7.4(43)	8.6(50)	19.3(112)	23.2(135)	36.7(213)	0.3(2)

The results indicate percentage and size: %(n)

Table 25. Frequency distribution: perception about stem cell research

ITEMS	NOT AT ALL	VERY LITTLE	LITTLE	TO SOME EXTENT	QUITE A LOT	A LOT	DON'T ANSWER
Science at the service of politics is dangerous	14.8(86)	14.6(85)	10.3(60)	19.3(112)	18.9(110)	21.7(126)	0.3(2)
Science at the service of politics is useful	10.5(61)	6.2(36)	7.1(41)	17.9(104)	32(186)	26.2(152)	0.2(1)
There must be research into science at the service of politics	28.7(167)	10.5(61)	10.8(63)	14.3(83)	18.1(105)	17.2(100)	0.3(2)
I am worried about the undesired effects of science at the service of politics	7.2(42)	8.3(48)	10.2(59)	17(99)	23.9(139)	33(192)	0.3(2)
I am worried about the use which may be made of science at the service of politics	4(23)	7.1(41)	7.6(44)	17.7(103)	24.8(144)	38.7(225)	0.2(1)
Science at the service of politics is beneficial to society	14.5(84)	11.2(65)	11.4(66)	18.6(108)	22.2(129)	22(128)	0.2(1)
Research into science at the service of politics must be controlled	4.6(27)	5.3(31)	7.1(41)	16(93)	26.9(156)	39.9(232)	0.2(1)

The results indicate percentage and size: %(n)

Table 26. Frequency distribution: perception about science at the service of politics

FUNTIONS	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
Solving problems	0	5	4.7	0.7
Obtaining knowledge	0	5	4.8	0.6
Obtaining economic benefits	0	5	4.3	0.9
Orientating political decisions	0	5	3.7	1.3
Helping people with their daily lives	0	5	4.3	0.9

Table 27. Descriptive statistics: the functions of science

SOME OPINIONS ABOUT SCIENCE

The most remarkable result is the low percentage of respondents who agree that citizens should be involved in decision-making, in issues related to the functioning of science (e.g. public funding) and in decision-making on issues with a social impact. Respondents tend to agree that science and technology solve problems but also create them. Lastly, they do not consider science subjects to have been a problem when they were in school (Table 28).

INTEREST

THE DESIRE TO KNOW ABOUT SCIENCE

Respondents are very interested in all the topics presented, especially astronomy and gravitational waves. They are also quite interested in the nature of science (how science is made) (Table 29).

WHAT DOES BEING INTERESTED IN SCIENCE MEAN?

This question aims to identify what people have in mind when they say they are or not interested in science. The problem is that it does not discriminate; there is a clear ceiling effect. Respondents largely associate each item with interest in science. Nevertheless, two groups can be identified based on the values of both the means and the standard deviations. In this sample, being interested in science is mostly associated with wanting to understand the world, keeping an eye out for new scientific and technological developments, reading items on new scientific discoveries and finding out about science products and applications which are useful to society. On the other hand, the somewhat less relevant elements to identify what it means to be interested in science are attending conferences and talks on science and technology, wanting to know how scientists work, visiting science and technology museums and exhibitions, and paying attention to news about the negative consequences of science and technology (Table 30).

ITEMS	NOT AT ALL	VERY LITTLE	LITTLE	TO SOME EXTENT	QUITE A LOT	A LOT	DON'T ANSWER
It is best to leave decisions on matters related to science and technology which have social repercussions in the hands of experts	3.6(21)	4.6(27)	5(29)	17.7(103)	36(209)	32.9(191)	0.2(1)
Some way must be found so that citizens can take part in the making of decisions on the operation of science, for example which research projects receive public funding	8.8(51)	7.4(43)	14.8(86)	28.2(164)	25.1(146)	15.5(90)	0.2(1)
Science and technology solve problems but they also create them	6(35)	13.8(80)	17.9(104)	34.1(198)	19.1(111)	9.1(53)	0
Citizens must participate in the making of decisions on science and technology which have to do with matters directly affecting them, for example the regulation of genetically modified foods	9.6(56)	9.3(54)	13.8(80)	25.3(147)	26.5(154)	15.3(89)	0.2(1)
I have always been bad at science subjects	46.1(268)	22(128)	13.3(77)	10.7(62)	5.5(32)	2.4(14)	0
The first impression is what counts	37(215)	25.5(148)	17.6(102)	13.4(78)	5(29)	1.4(8)	0.2(1)
What is scientific evidence today may not be tomorrow	5.5(32)	11.2(65)	11.2(65)	23.9(139)	25.3(147)	22.5(131)	0.3(2)

The results indicate percentage and size: %(n)

Table 28. Frequency distribution: opinions about science

ITEMS	NOT AT ALL	VERY LITTLE	LITTLE	TO SOME EXTENT	QUITE A LOT	A LOT	DON'T ANSWER
Know more about biotechnology	1.5(9)	1(6)	4.1(24)	17.4(101)	38.4(223)	37.5(218)	0
Learn more about the risks of biotechnology	1.4(8)	1.2(7)	4.3(25)	19.1(111)	39.2(228)	34.4(200)	0.3(2)
Understand better how genetic engineering contributes to food production	2.9(17)	1.2(7)	3.8(22)	16.5(96)	37.5(218)	38(221)	0
Know more about the Universe	1.5(9)	1.2(7)	3.4(20)	11(64)	24.6(143)	58(337)	0.2(1)
Learn more about gravitational waves	1.5(9)	4.3(25)	5.2(30)	16.9(98)	27.2(158)	44.8(260)	0.2(1)
Understand better the repercussions of this discovery	2.2(13)	1.7(10)	2.9(17)	12.4(72)	28.6(166)	52(302)	0.2(1)
Know more about nuclear power	2.1(12)	1.7(10)	6.5(38)	20.1(117)	32.2(187)	37.3(217)	0
Learn more about the contribution of nuclear power to the world energy pool	2.8(16)	2.4(14)	7.9(46)	22.4(130)	31.2(181)	33.4(194)	0
Understand better how nuclear power stations work	4(23)	2.2(13)	8.1(47)	19.4(113)	30.8(179)	35.5(206)	0
Know more about how science is made	1.4(8)	2.2(13)	3.4(20)	12.9(75)	32.7(190)	47.3(275)	0
Learn more about the process of obtaining a vaccine	2.2(13)	2.2(13)	4.5(26)	16.4(95)	29.1(169)	45.6(265)	0
Understand better which are the steps which convert scientific research into a product available to citizens	1.9(11)	1.9(11)	4.5(26)	14.6(85)	30.8(179)	46.1(268)	0.2(1)

The results indicate percentage and size: %(n)

Table 29. Frequency distribution: the desire to know about science

FEATURES	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
Visiting science and technological museums and exhibitions	0	6	4.7	1.3
Keeping an eye out for new scientific and technological developments	1	6	5.3	1
Reading news items on new scientific discoveries	1	6	5.3	0.9
Keeping an eye out for news on the negative consequences of science and technology	1	6	4.7	1.33
Wanting to know how scientists work and what tools they have at their disposal	1	6	5.1	1.1
Wanting to understand the world and how it works and why	1	6	5.6	0.9
Finding out about science products and applications which are useful to society	1	6	5.2	1
Attending lectures and talks on science and technology	1	6	4.8	1.3

Table 30. Frequency distribution: the meaning of being interested in science

EPILOGUE

The initiatives implemented to manage the relationship between society and science have relied mainly on the idea that there is a certain public rejection of scientific and technological developments that is due to a deficit of knowledge, trust or commitment. Therefore, citizens were the subject of different requests. In a first stage they were requested scientific literacy. In a second one they were requested trust. And presently they are requested to be engaged. The chief aim is to engage all social actors (researchers, industry, politicians and civil society) in the research and innovation process to improve the dialogue between science and the rest of society. However, the strategy adopted is still primarily aimed at increasing public interest in science by hook or by crook. Therefore, surveys on public perception of science repeatedly reflect high figures of citizen interest, but a very limited willingness to engage. For example, data from the 2020 edition of the survey on public perception of science and technology carried out in Spain by the Spanish Foundation for Science and Technology (FECYT) indicate that there are 37.7% of respondents that are highly or quite interested in science, 33.3% interested to some extent, 19.3% little interested and 9.1% very little interested. Using a three points response scale, the results for Spain of the 2021 Eurobarometer on science and technology (Special Eurobarometer 516) indicate that 41% of the respondents are very interested in new scientific and technological developments, 45% are moderately interested and 14% are not interested at all.

The results we have obtained show a very different picture. At best, only 2% of the people contacted felt sufficiently interested or curious regarding science to click on the Facebook ad, despite it being an action demanding minor commitment and effort on their part. On the other hand, the very low response rate that we have obtained can be explained by a combination of two factors: people's low actual interest in science and the survey's high demands in terms of time and effort. Only very interested people will be willing to make such an effort. As a result, 78% of our sample is interested (a lot or quite a lot) in science, 2.6% is interested to some extent, 10.7% is a little or very little interested in the issue and 0.3% is not interested at all.

Regarding the willingness to participate in decision-making on issues related to science and technology, data from the FECYT survey show that nearly 11% of the population would like to participate actively in decision-making, 20% would like to have the opportunity to give their opinion, 21% would like citizens to participate in decision-making even though they do not want to get personally involved and 42% are not interested in getting involved. In the PIKA sample these percentages are 24.6%, 31.5%, 16% and 19%, respectively.

PIKA respondents are interested in science and willing to be involved in the relationship between science and society. It can be said that we have identified a cluster of what can be called "'critical engagers', that is, critically minded, socially responsible individuals who tend to engage in and give an opinion concerning S&T change, combining an overall optimistic attitude with the perception of significant threats in particular fields of application [with] a mature and intelligent stance that may well be employed in enhancing the relations between science and society" (Cámara et al., 2018, p. 692).

The citizens we have identified appear to be somewhat science "advocates", albeit not in the sense that they adhere to a mythical vision of science, but that they feel the need to protect it. This was the argument provided by participants in the pilot study when asked about the reasons why they were not in favour of citizens engaging in decisions about science and technology, especially those related to funding and selecting research areas. It might be that the tepid attitude towards science for policy also reflects respondents' concern that science might be corrupted by politics. This is an interesting hypothesis that should be explored, considering the increasingly close link between science and politics.

Lastly, despite having obtained a very biased sample, we were also able to attract people with a more moderate perspective of science, and also others with a clearly negative attitude. The possibility of comparing these groups, despite being imbalanced in size, is most promising.

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ANEX: PIKA QUESTIONNAIRE (PERCEPTION, INTEREST, KNOWLEDGE, AND ACTIONS) ON THE IMAGE OF SCIENCE

At the CTS Research Unit of the Centre for Energy, Environmental, and Technological Research (*Centro de Investigaciones Energéticas, Medioambientales, y Tecnológicas,* CIEMAT) we study the image citizens have of science and technology.

Up to now insufficient attention has been paid to people and we would like to change this. This is why we need your help to answer a series of questions which will allow us to find out what science means to you.

It is important for you to answer honestly. There are no good or bad options or options better than others. All are valid and necessary to us.

The questionnaire is anonymous and is divided into two parts. The first of these will allow us to obtain a detailed image. The second is designed to analyse certain hypotheses on the factors which influence the image of science.

Please do not leave any question blank; we need all of them.

It takes about 40 minutes to complete the questionnaire. Before starting you must take into account that you cannot leave off in the middle and come back to it later; you must answer all the questions in one go. You have time to think about your answer. The deadline for handing in the questionnaire is day XXXX of 2021.

We have thought that it might be interesting for you to be sent some information on the results you have obtained. This is why once you have answered all the questions a profile will appear with some of the characteristics which help to define what science means to you.

Many thanks for taking part!

When you're ready you can begin.

SECTION 1:

Question 1: As an expert on science communication said recently at an interview: "There is no doubt that we are living in very interesting times as far as science is concerned. Before the pandemic we got to know the results of scientific research when they had been processed, published, and consolidated. But now we are seeing how it works in real time with all the uncertainty, confusion, and discrepancy that this involves".

We would like to know where you usually look for information (if you do so) on these subjects (you can tick up to three answers in order of preference).

1) I don't usually look for information.
2) Friends.
3) Family.
4) Books or other publications.
5) Press.
6) Radio.
7) Television.
8) Internet.

Question 1B*: [If "8) Internet" is ticked]:* You have selected "Internet". In this case where do you look for information? (you can tick up to three answers in order of importance).

1) Social networks (Twitter, Facebook, Instagram, Linkedin, …).
2) Blogs, forums, or chats.
3) Search engines (such as Google).
4) Institutional websites (Ministries, the World Health Organisation, companies and corporations…).
5) Information sent by friends or acquaintances.
6) Wikis.
7) The media (press, radio, television...).
8) Messaging services (Whatsapp, Telegram…).
9) Newsletters or alerts.

Question 1C: Which of the following sentences best reflects your opinion on the information available on the Internet?

1) In general you can't trust the Internet; almost all the information on it is misleading

2) On the Internet there is information of good quality but most of it is misleading

3) Some of the information on the Internet is misleading although most of it is of good quality

4) On the Internet there is both good quality information and misleading information; the important thing is to know where to look

5) In general you can trust the Internet; most of the information on it is of good quality

Question 1D: To what extent do you trust the information that can be obtained on social networks?

1) Not at all

2) Very little

3) Not much

4) To some extent

5) Quite a lot

6) A lot

Question 2: How often do you do the following actions?

	Definitely not	Probably not	I think I wouldn't	I think I would	I probably would	I definitely would
Requesting or providing technical, scientific, or academic information in forums, chats, social networks, and other similar tools						
Making searches on the Internet in order to understand news about or information on science and technology correctly						
Retweeting or sharing on other social networks news about or information on science and technology						
Asking someone for help (family, friends, teachers…) so as to better understand news about or information on science and technology						
Creating specific contents for blogs or websites of a technical, scientific, or academic nature						
Giving your opinion in a discussion on a scientific matter on a social network or a forum on the Internet						

Question 3: In which of the following activities would you take an active part if you received an invitation to do so?

	Definitely not	Probably not	I think I wouldn't	I think I would	I probably would	I definitely would
Watching a show of monologues on science						
Attending a popular science lecture						
Visiting an online exhibition on the most noteworthy advances of the year in science and technology						
Taking part in a citizens' enquiry to decide which science projects should receive public financing						
Taking part in a virtual demonstration to demand more public funds for scientific research						
Signing a petition to request the consultation of citizens in decisions on science and technology which directly affect them						
Taking part in dialogues between citizens, scientists, and political leaders to discuss subjects related to the operation of science						
Taking part in dialogues between citizens, scientists, and political leaders to discuss subjects related to the consequences of scientific development for citizens						
Taking part in a citizens' science activity, i.e. providing some form of assistance to scientists in the carrying out of their research						

Question 4: You will find below a series of sentences describing behaviour which people may engage in during their daily life. For each of them please tell us how often you engage in the behaviour:

	Never	Hardly ever	Not often	From time to time	Often	Very often
Talking of science with your friends when an important discovery, such as the Higgs boson or proof that gravitational waves exist, comes up on the news						
Looking for information to find out what to do when a news item related to science and technology which affects you comes up (for example, COVID-19 treatment and vaccination)						
Taking part in collecting signatures or in demonstrations on subjects related to science and technology (for example nuclear power, biotechnology, the environment...)						
Taking part in lectures or other popular science activities (Science Week, scientific monologues, museums or exhibitions…)						
Consulting different sources to test the information you receive						
Resending automatically to your acquaintances and relatives the information you receive by other channels (e-mail, Whatsapp, etc.)						

Question 5: When the rocks in space enter the atmosphere of a planet they become meteoroids. Meteoroids heat up and shine as they fall through the atmosphere. Most of them disintegrate before reaching the Earth's surface. As the meteoroid approaches the Earth it accelerates. Why does this occur?

1) It is repelled by the surface of the Sun
2) It is attracted by the mass of the Earth
3) It is attracted by the rotation of the Earth

When a meteoroid crashes into the surface of a planet it becomes a meteorite; if it is large enough its impact produces a crater. What is the relationship between the atmosphere of a planet and the number of craters on its surface?

1) There is no relation between the number of craters and the atmosphere of the planet
2) The thicker the atmosphere the more craters there will be, because there will be fewer meteoroids which disintegrate in the atmosphere
3) The thicker the atmosphere the fewer craters there will be, because there will be more meteoroids which disintegrate in the atmosphere

There has recently been a major discovery in the field of astronomy: the existence of gravitational waves has been detected. This discovery is very important because:

1) It confirms a prediction made by the physicist Isaac Newton
2) It has confirmed a prediction of the Theory of General Relativity
3) It has generated the need for a radical change in astronomy research

Question 6: "Energy is neither created nor destroyed, it simply transforms itself".

1) It is an advertising slogan.

2) It describes Newton's first law.

3) It states the first principle of thermodynamics.

Energy in nuclear power stations is produced:

1) By nuclear fusion.

2) By nuclear fission.

3) By the combustion of radioactive elements.

The Fukushima accident revived the social debate about the advisability of maintaining nuclear power stations in other countries. Please tell us which of the following options seems to you to best describe the result of this debate:

1) Nuclear power stations are completely safe in those areas which are not liable to tsunamis.

2) Nuclear power stations are completely safe in those countries not threatened by seismic activity or terrorism.

3) Nuclear power stations can never be considered to be completely safe.

Question 7: If we understand cloning to be the generating of a living creature with the same genetic load as another:

1) It has never occurred spontaneously in nature.

2) It occurs spontaneously in nature.

3) It has never occurred either naturally nor artificially.

Therapeutic cloning:

1) Is an assisted reproduction technique that has been habitually used for decades.

2) Is not orientated towards the cloning of animals or people but of tissues or organs.

3) Reproduces in the laboratory the development of embryos of identical twins.

The debate about cloning is due to:

1) The possibility of using it to produce transgenic foods.

2) The possibility of using it for the reproduction of human beings.

3) The fact that it is being used indiscriminately in the Third World.

Question 8: Where are the neutrons in an atom?

1) In the nucleus.
2) Outside the nucleus.
3) Orbiting around the nucleus.

What is the Higgs boson?

1) A chemical reagent.
2) A particle.
3) A fossil.

How was the Higgs boson discovered?

1) Owing to a chemical reaction.
2) In an experiment designed to find it.
3) On an archaeological expedition.

Question 9: Genes:

1) May change if you eat a genetically modified food.
2) Determine which diseases you will have throughout your life.
3) Are units of biological information.

Which of the following affirmations is NOT correct?

1) Biotechnology is a technique which uses living organisms or parts of them to modify products for practical purposes.
2) Biotechnology is used in traditional agriculture and has allowed the production of bread, beer, and cheese.
3) Biotechnology is a technique which is beginning to be used after the discovery of the structure of DNA.

As in many applications of science, genetically modified foods also give rise to debate. Which of the following affirmations best describe the risk of this type of food?:

1) It has been shown that the consumption of genetically modified foods involves considerable risk to health.
2) Genetically modified foods give multinationals the possibility of appropriating the seed supply.
3) Genetically modified foods increase inequalities and contribute towards there being more hunger and poverty in the world.

Question 10: Which of the following options is the correct one?

1) The number pi (π) is a whole number
2) The number pi (π) has infinite decimals
3) Pi (π) is a constant which has been discovered recently

Pi (π):

1) Defines the relation between the legs and the hypotenuse of a triangle
2) Defines the value of the acceleration of gravity on Earth
3) Can be applied among other things to the manufacture of tyres

We will now give you a heading whch appeared in a national newspaper some time ago: "Majority support for the proposal to maintain the final examination as a requirement for entering university" The subtitle was as follows: "80% of the students who have taken part in the voting supported the measure. 25% of the students consulted replied". Which of the following sentences best expresses the result obtained by the voting?

1) The news item indicates that there is majority support because 80% of the students are in favour of the measure
2) The news item indicates that eight out of every ten students consulted are in favour and 25% are against
3) The news item indicates that 80% of the participants are in favour although three out of four did not give their opinions

Question 11. To what extent do you believe that knowledge of science and technology is useful to you in your daily life? We give you several options.

Action	No use	Very little	Little use	Some use	Quite useful	Very useful
In understanding the world						
In healthcare and the prevention of diseases						
In caring for the environment						
When making decisions as a consumer						
In your profession or job						

Question 12: Thinking about the next 20 years, do you think that the development of science and technology will bring:

1) Many benefits
2) Quite a few benefits
3) Some benefits
4) Few benefits
5) Very few benefits
6) No benefit

Question 13: Thinking of the next 20 years, do you think that the development of science and technology will generate:

1) Many risks
2) Quite a few risks
3) Some risks
4) Few risks
5) Very few risks
6) No risk

Question 14: To what extent do you agree with the following sentences on genetically modified or transgenic foods?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Transgenic foods are dangerous						
Transgenic foods are useful						
There must be research into transgenic foods						
I am worried about the undesired effects of transgenic foods						
I am worried about the use which may be made of transgenic foods						
Transgenic foods are beneficial to society						
Research into transgenic foods must be controlled						

Question 15: When you think of "science” to what extent do these ideas come to mind? 0 means that you don't think about it at all and 5 that you think a lot about it.

Risk	0	1	2	3	4	5
Boredom	0	1	2	3	4	5
Usefulness	0	1	2	3	4	5
Safety	0	1	2	3	4	5
Difficulty	0	1	2	3	4	5
Mistrust	0	1	2	3	4	5
Benefit	0	1	2	3	4	5
Uncertainty	0	1	2	3	4	5
Knowledge	0	1	2	3	4	5

Question 16: there tends to be a lot of talk on what the population thinks of science, but we are also interested in knowing what you feel when you think of it. We would like you to tell us to what extent you feel worried if you think about these characteristics which describe science and technology:

	A lot	Quite a lot	To some extent	Little	Very little	Not at all
Uncertainty is a characteristic of science						
Scientific research depends more and more on business interests						
When decisions are made on matters related to science which have repercussions for all of us, citizens are not asked for their point of view						
We depend more and more on science and technology in our daily lives						
News on science says one thing one day and the opposite the next						
Science and technology applications are available for anyone to use whatever their intention						
Science and technology are so complicated that few people can really understand them						
Scientific and technological progress occurs so fast that the authorities cannot control it properly						
Science is too closely related to politics						
Scientific and technological development may have unexpected side effects						
Most of the time scientists disagree with each other						
The research budget in Spain is lower than that of other European countries						

Question 17: To what extent do you agree with the following sentences on cloning?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Cloning is dangerous						
Cloning is useful						
There must be research into cloning						
I am worried about the undesired effects of cloning						
I am worried about the use which may be made of cloning						
Cloning is beneficial to society						
Research into cloning must be controlled						

Question 18: To what extent do you agree with the following sentences on nuclear power?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Nuclear power is dangerous						
Nuclear power is useful						
There must be research into nuclear power						
I am worried about the undesired effects of nuclear power						
I am worried about the use which may be made of nuclear power						
Nuclear power is beneficial to society						
Research into nuclear power must be controlled						

Question 19: To what extent do you agree with the following sentences on artificial intelligence?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Artificial intelligence is dangerous						
Artificial intelligence is useful						
There must be research into artificial intelligence						
I am worried about the undesired effects of artificial intelligence						
I am worried about the use which may be made of artificial intelligence						
Artificial intelligence is beneficial to society						
Research into artificial intelligence must be controlled						

Question 20: What about these on stem cell research?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Stem cell research is dangerous						
Stem cell research is useful						
There must be stem cell research						
I am worried about the undesired effects of stem cell research						
I am worried about the use which may be made of stem cell research						
Stem cell research is beneficial to society						
Stem cell research must be controlled						

Question 21. Science may perform different functions. To what extent do you consider that science is useful for…?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Solving problems						
Obtaining knowledge						
Obtaining economic benefits						
Orientating political decisions						
Helping people with their daily lives						

Question 22: Saying that science is at the service of politics means that scientific knowledge is used to facilitate or improve political decision-making. Taking this into account, to what extent do you agree with the following sentences?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Science at the service of politics is dangerous						
Science at the service of politics is useful						
Science must be at the service of politics						
I am worried about the undesired effects of science at the service of politics						
I am worried about the use which may be made of science at the service of politics						
The fact that science at the service of politics exists is beneficial to society						
Science at the service of politics must be controlled						

Question 23: In various studies citizens' opinions on science have been obtained. You will find below some of the replies given by other people in these studies. To what extent do you agree with them?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
It is best to leave decisions on matters related to science and technology which have social repercussions in the hands of experts						
Some way must be found so that citizens can take part in the making of decisions on the operation of science, for example which research projects receive public funding						
Science and technology solve problems but they also create them						
Citizens must participate in the making of decisions on science and technology which have to do with matters directly affecting them, for example the regulation of genetically modified foods						
I have always been bad at science subjects						
The first impression is what counts						
What is scientific evidence today may not be tomorrow						

Question 24: According to the FAO (Food and Agriculture Organisation) the development of biotechnology to contribute to the sustainable development of agriculture, fishing, and forestry will be able to meet to a large extent the food needs and means of subsistence of the world population. Biotechnology goes much further than genetic engineering, but what makes the latter at the same time a great hope and a source of concern is its capacity to transfer genes between different species. Taking this into account:

To what extent do you agree with these sentences?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Applying genetic engineering to the obtaining of food is very dangerous						
The FAO should not promote the development of biotechnology for the obtaining of food						

And to what extent would you like to....?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Know more about biotechnology						
Learn more about the risks of biotechnology						
Understand better how genetic engineering contributes to food production						

Question 25: *Science*, one of the most prestigious journals of the scientific community, has pointed out that the detection of gravitational waves, tiny disturbances in the space-time fabric which cross the Universe at the speed of light, has been one of the most important scientific findings of recent times. To what extent would you like to…?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Know more about the Universe						
Learn more about gravitational waves						
Understand better the repercussions of this discovery						

Question 26: According to the IAEA (International Atomic Energy Agency), nuclear power gives access to clean, reliable, and cheap energy. It is an important part of the world energy pool and it is expected that its use will increase in the forthcoming decades. Taking this into account:

To what extent do you agree with this sentence?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
It is to be expected that the IAEA speaks well of nuclear energy. After all, they have interest in the subject.						

And to what extent would you like to....?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Know more about nuclear power						
Learn more about the contribution of nuclear power to the world energy pool						
Understand better how nuclear power stations work						

Question 27: there is no doubt that the COVID-19 pandemic has put science in the centre of our lives. For the first time we are hearing about science and its products in real time as we go along. To what extent would you like to…?

	Not at all	Very little	Little	To some extent	Quite a lot	A lot
Know more about how science is made						
Learn more about the process of obtaining a vaccine						
Understand better which are the steps which convert scientific research into a product available to citizens						

Question 28: What does being interested in science and technology mean to you? Assess the following options on a 4-point scale on which 1 means that it has nothing to do with it and 4 that it has a lot to do with it.

Visiting science and technological museums and exhibitions	0	1	2	3	4	5
Keeping an eye out for new scientific and technological developments	0	1	2	3	4	5
Reading news items on new scientific discoveries	0	1	2	3	4	5
Keeping an eye out for news on the negative consequences of science and technology	0	1	2	3	4	5
Wanting to know how scientists work and what tools they have at their disposal	0	1	2	3	4	5
Wanting to understand the world and how it works and why	0	1	2	3	4	5
Finding out about science products and applications which are useful to society	0	1	2	3	4	5
Attending lectures and talks on science and technology	0	1	2	3	4	5

Question 29. Can you tell us to what extent these sentences describe your character? 0 means that they do not describe it at all and 5 that they describe it perfectly

I tend to take risks in order to progress in life, even when I am not sure what will happen	0	1	2	3	4	5
I tend to be open to new ideas and new ways of doing things or of thinking	0	1	2	3	4	5
I tend to plan the future in advance	0	1	2	3	4	5
I have a high opinion of people who question traditional ways of acting	0	1	2	3	4	5
I try to learn new things continuously	0	1	2	3	4	5
I prefer to do important things myself without much help from others	0	1	2	3	4	5

SECTION 2

Question 1: When you have to face a problem or make a decision, to what extent do you search for information, concern yourself about analysing the situation, and think about it?

1) To be honest not much. I don't consider myself to be a particularly thoughtful person.
2) I would like to do it, but I find it hard. It seems to me that it requires a lot of effort.
3) I usually do so. I like to understand the reason for things and I devote a certain amount of time to investigating this, without going too far.
4) I put a lot of effort into doing so. I think it is necessary to analyse matters thoroughly.

Question 2: In your opinion, how much do you know about science?

1) A lot
2) Quite a lot
3) A certain amount
4) Little
5) Very little
6) Nothing

Question 3: Do you consider yourself to be interested in science and technology?

1) A lot
2) Quite a lot
3) A certain amount
4) Little
5) Very little
6) Nothing

Question 4. Which of the following affirmations best describes your opinion on participation in making decisions which have to do with scientific matters and also have social implications (such as for example the management of the COVID-19 pandemic?

1) I am not interested in getting involved in making decisions on scientific matters

2) I would like citizens to be able to take part in making decisions on scientific matters, but I do not want to be personally involved

3) I would like to be able to state my opinions on decisions which have to do with scientific matters

4) I would like to be actively involved in the making of decisions on scientific matters

5) I am quite willing to get involved in the making of decisions on scientific matters

To continue we will ask you the last 6 questions, which as we said at the beginning will help us to understand better the image you have of science. For this reason it is very important for you to answer all of them. Please don't leave them blank. This is the last effort.

Question 1: Which of the following options is a synonym of the word boar?

1) Pain
2) Tiresome
3) Hog
4) Ladle

Question 2: Which of the following series of words is NOT in alphabetical order?

1) Acclaim, android, enumerate, establish
2) Abate, abandon, astronaut, aviation
3) Calendar, camper, cannon, castrated
4) Lake, leopard, list, lunatic, lupin

Question 3: Complete the following analogy:

Beech is to … as Seek is to…

1) Find – Beach
2) Adverb – Noun
3) Find – Discover
4) Tree – Discover

Question 4: The cafeteria of the National Museum of Science and Technology is subsidised. For this reason, breakfast including a coffee and toast costs 1.40 euros. Taking into account that the coffee costs 1 euro more than the toast, how much does the toast cost?

1) 10 cents.
2) 20 cents.
3) 30 cents.
4) 40 cents.

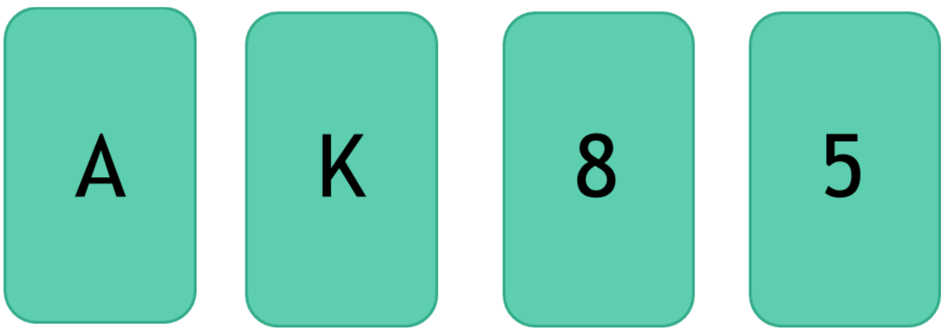
Question 5: A researcher wishes to take a culture of a recently discovered bacterium in order to study it. For this purpose he places a bacterium in a Petri dish and begins to analyse its rate of reproduction. He immediately realises that each day there are double the number of bacteria of the previous day. If it takes 24 days for the Petri dish to be filled, how many days will it take for it to be half full?

1) 4 days.
2) 9 days.
3) 12 days.
4) 23 days.

Question 6: Scientists analysing the effects of radioactivity in seeds have designed a robot to take charge of planting the seeds in enclosures specially prepared for cultivation with the aim of avoiding the risks of contamination. If 5 robots take 5 minutes to plant 5 seeds, how long will 100 robots take to plant 100 seeds?

1) 5 minutes.
2) 10 minutes.
3) 15 minutes.
4) 100 minutes.

Question 7:



In the image you can see four cards, each of which has a letter on one side and a number on the other. We want to test the following hypothesis: when a card has a vowel on the side of the letter it has an even number on the side of the number. Which cards do we have to turn over to find out whether the hypothesis is correct?

a) The one with the K and the one with the 8
b) The one with the K and the one with the 5
c) The one with the A and the one with the 8
d) The one with the A and the one with the 5

CLASSIFICATION VARIABLES

Now we have almost finished. Although the survey is anonymous, we need to know some basic information about you in order to carry out our study:

Age:	**Age:**	**Sex**:
1) 16-20	1) 16-35	1) Male
2) 21-25	2) 36-65	2) Female
3) 26-30	3) Over 65	
4) 31-35		
5) 36-40		
6) 41-45		
7) 46-50		
8) 51-55		
9) 56-60		
10) 61-65		
11) 66-70		
12) 71-75		
13) 76-80		
14) 81-85		
15) 86-90		

What is the **maximum level of studies** which you have completed?

1) No official qualifications.

2) Primary Education, Certificate of Primary Studies, General Basic Education (*Educación General Básica*, EGB) years 1 to 5, and similar.

3) Compulsory Secondary Education (*Educación Secundaria Obligatoria*, ESO), General Basic Education (*Educación General Básica*, EGB) years 6 to 8, lower examinations, occupational training, task learning programme, social insertion programme (1 year), initial professional qualifications programme (2 years), entrance tests for intermediate vocational training, specific occupational training, and similar.

4) Initial professional qualifications programme (1 year), professional technical teaching for adults, certificate of accreditation, occupational training, and similar.

5) Intermediate specific professional training, intermediate certificate from the Official School of Languages, university entrance examination for students aged over 25, the old Occupational Training (1 year), Occupational Training I, and similar.

6) Secondary education, old higher secondary education and pre-university courses, Unified Secondary Education (*Bachillerato Unificado Polivalente*, BUP) and the Career Orientation Course (*Curso de Orientación Universitaria*, COU), Occupational Training II, Master of Industry, and similar.

7) Entrance tests for higher vocational training and similar.

8) Higher specific occupational training, higher certificate of music and dance, higher certificate of plastic arts/design/sports technician, or similar.

9) Diploma course, engineering and technical architecture; degree in higher engineering and architecture, degree certificates, and similar.

10) Master's degree courses & postgraduate healthcare specialities and similar

11) Doctorate

12) Non-Spanish qualifications *[Open answer]*

From which field were these studies? (If they were from more than one field, state the most important; if you hold several qualifications of the same level, select the most recent)

1) General training programmes.

2) Natural science.

3) Engineering and technology.

4) Medicine and health sciences.

5) Social sciences, commerce/business studies, and law.

6) Teacher training and education sciences.

7) Languages, arts, and humanities.

Profession: *[Open answer]*

Does anyone in your family have or has had a job or hold a university degree in science or technology?

1) Yes, my father.

2) Yes, my mother.

3) Yes, a brother or sister.

4) Yes, another member of my family.

5) No, no-one in my family.

You've finished! Many thanks for your collaboration. If you would like to be kept informed of the progress of our study, please contact us directly at the following e-mail address: uicts@ciemat.es. Naturally getting in touch with us involves no commitment of any kind and you can tell us that you want us to eliminate your e-mail address from our list of contacts at any time.

Thank you once again.

INCLUDE PROFILE