Evaluation of the impact of graphical abstracts on science communication to non-expert audiences

Mariana Campos
Master's in science education and communication
Science education unit
Faculty of Sciences of the University of Porto
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Mariana Campos

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Supervisor
Prof.ª Maria João Santos, Faculty of Sciences of the University of Porto

Co-supervisor
Prof.ª Cristina Ferreira, Faculty of Fine Arts of the University of Porto

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FACULDADE DE BELAS ARTES
UNIVERSIDADE DO PORTO

“Make everything as simple as possible, but not simpler. “

Albert Einstein

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Resumo

Desde o século XVII, a publicação científica tem sido o meio mais confiável de disseminação do conhecimento, embora a sua estrutura tenha permanecido praticamente inalterada. Atualmente, embora o acesso à informação seja facilitado, a desinformação é abundante, desafiando a relação entre o público e a ciência. O graphical abstract estilo infográfico pode ser a chave para minimizar este desafio, oferecendo informações confiáveis de forma mais atrativa e acessíveis a audiências não especializadas. Contudo, existem poucos dados sobre o seu impacto real. Motivados pela necessidade de uma comunicação científica eficaz, esta investigação visa avaliar a eficácia destes elementos no envolvimento do público não especialista com a ciência. Considerando os recursos financeiros e humanos envolvidos na implementação de graphical abstracts estilo infográfico em artigos científicos, pretendemos através de um estudo comparativo por meio de questionário avaliar possíveis diferenças significativas no interesse, interação e compreensão de um público não especialista ao ser exposto a um graphical abstract estilo infográfico versus um abstract textual. Neste sentido foram desenvolvidos e integrados nos questionários 3 graphical abstracts estilo infográfico. Os resultados, baseados numa amostra de 214 participantes, mostram um impacto positivo e significativo dos graphical abstracts estilo infográfico promovendo o interesse imediato e prolongado dos participantes, melhorando a perceção de importância do tema, potenciando o impacto do artigo científico ao qual se refere e facilitando a interação do público com tópicos científicos em social networks. O nível de compreensão dos participantes não sofreu alterações significativas quando comparando o elemento gráfico e o abstract textual. Finalmente, o aumento do interesse dos participantes refletiu-se num impacto significativo em todas as outras variáveis analisadas. Os dados suportam o potencial de graphical abstracts estilo infográfico como ferramenta eficaz de comunicação científica, contribuindo para sociedades mais informadas e envolvidas com a ciência. Embora a plena implementação destes elementos ainda exija mais investigação, soluções temporárias como “tool kits” podem ser eficazes para permitir aos investigadores comunicar as suas pesquisas neste formato.

Palavras-chave: Ferramenta de comunicação de ciência, questionário, avaliação de impacto.

Abstract

Since the 17th century, scientific publication has been the most reliable mean of disseminating knowledge, although its structure has remained virtually unchanged. Currently, despite facilitated access to information, misinformation is abundant, challenging the relationship between the public and science. The **infographic-style graphical abstract** may be key to mitigating this challenge, offering reliable information in a more attractive and accessible way to non-specialist audiences. However, there is little data on its real impact. Motivated by the need for effective scientific communication, this research aims to evaluate the effectiveness of these elements in engaging the nonspecialist public with science. Considering the financial and human resources involved in implementing infographic-style graphical abstracts in scientific articles, we intend to evaluate possible significant differences in interest, interaction, and understanding of a non-specialist audience when exposed to an infographic-style graphical abstract versus a textual abstract through a comparative study using questionnaires. To this end, 3 infographic-style graphical abstracts were developed and integrated into the questionnaires. The results, based on a sample of 214 participants, show a positive and significant impact of infographic-style graphical abstracts, promoting immediate and prolonged interest of participants, improving the perception of the importance of the topic, enhancing the impact of the scientific article, and facilitating public interaction with scientific topics on social networks. The participant's level of understanding did not undergo significant changes when comparing the graphical abstracts to the textual abstract. Finally, the increased interest of participants was reflected in a significant impact on all other analysed variables. The data supports the potential of infographic style graphical abstracts as an effective scientific communication tool, contributing to more informed and engaged societies with science. Although the full implementation of these elements still requires more research, temporary solutions such as "tool kits" can effectively allow researchers to communicate their findings in this format.

Keywords: Science communication tool, survey, impact assessment.

Graphical abstract

Keywords: Science communication tool, survey, impact assessment.

Contents

List of Tables xi

List of Charts xiii

List of Figures xv

List of Abbreviations xvi

Chapter 1: Introduction 1

1.1. Background 1

1.2. Dissertation motivation 2

1.3. Dissertation objectives 3

Chapter 2: State of the art 5

2.1. Disclosure of science 5

2.1.1. Scientific research 5

2.1.2 Science dissemination vs science communication 6

2.1.2. Models of science communication 7

2.1.3. The new science: Science 2.0 8

2.1.3.1. The role of social media in Science 2.0 10

2.2. Communication theory 13

2.2.1. Effective communication 13

2.2.2. Types of communication 14

2.2.2.1 Verbal and non-verbal communication 15

2.2.2.2 Written communication 15

2.2.2.3 Visual communication 16

2.2.3. Visuals in science history 17

2.3. Graphical abstracts 21

2.3.1. Graphical Abstract 21

2.3.2. Definition and purpose 22

2.3.3 Types of graphical abstracts 23

2.3.4. Historic evolution 25

2.3.5. Fundamental elements 27

2.3.5.1. Content 27

2.3.5.2. Design 28

2.3.5.2.1 Design principles 28

2.2.6. Limitations 38

Chapter 3: Methodology 41

3.1. Research design 41

3.2. Survey design 43

3.2.1 Sampling 44

3.3. Survey development 45

3.3.1. GA development 45

3.3.1.1 *Anisakis* GAI 48

3.3.1.2 *Microplastic* GAI 50

3.3.1.2 *Seahorse* GAI 51

3.3.2. Survey structure 53

3.3.3. Questions 56

3.3.4. Answer options 58

3.3.5. Validity and reliability 60

3.4. Data Analysis 62

3.4.1. Parametric and non-parametric techniques 62

3.4.2. Differences between samples (non-parametric) 63

3.4.3. Correlation between variables (non-parametric) 63

Chapter 4: Results and Discussion 67

4.1. Sample characterization 67

4.1.1. Socio demo-graphic parameters 67

4.1.2. Scientific articles parameters 70

4.2. Comparison between GAs and TAs 74

4.2.1. *Anisakis* article 75

4.2.2. Microplastics article 85

4.2.3. Seahorse article 94

4.2.4. Overall discussion (three articles) 102

4.3. Interest influence on key variables 104

4.4. Experts perspectives 106

Chapter 5: Conclusion and future work 109

5.1. Conclusion 109

5.2. Future work 110

References 113

Attachment [1] – Support of the ethics committee 117

Attachment [2] - Survey 117

Attachment [3] – Answers first impression (*Anisakis*) 142

Attachment [4] – Answers first impression (MP's) 143

Attachment [5] – Answers first impression (Seahorse) 144

Attachment [6] – Answers disadvantages (Experts) 146

List of Tables

Table 1: Differences between Science dissemination and science communication. Adapted from: Gimeno, C., Communication vs Dissemination: What is the difference, I.h.E. Commission, Editor. 2018. 7
Table 2: Examples of Likert Scales 59
Table 3: Non-parametric statistic techniques. Adapted from: Hill, M.M.H., A., Investigação por questionário 2008, Lisboa: Edições Sílabo. 63
Table 4: Frequency of nationalities results. 68
Table 5: Description of profession results. 70
Table 6: Descriptive results of final question. 74
Table 7: Crosstable GA and TA (1st impression) – *anisakis*. 76
Table 8: Frequency of engagement and interaction variables TA section - anisakis. 77
Table 9: Frequency of engagement and interaction variables GA section - anisakis. 77
Table 10: Significance of the differences between GA and TA in engagement and interaction variables - anisakis. 79
Table 11: Increase (%) of each variable - anisakis. 80
Table 12: Kruskal-Wallis H test results (reading frequency / agreement) – anisakis. 81
Table 13: Kruskal-Wallis H test results (age/probability). 82
Table 14: GA and TA frequency results on comprehension - *anisakis*. 83
Table 15: Comprehension results of question 1 - anisakis. 83
Table 16: Comprehension results of question 2 - *anisakis*. 84
Table 17: Crosstable GA and TA 1st impression – microplastics. 86
Table 18: Frequency of engagement and interaction variables TA section - microplastics. 87
Table 19: Frequency of engagement and interaction variables GA section - microplastics. 87
Table 20: Significance of the differences between GA and TA in engagement and interaction variables - microplastics. 89
Table 21: Increase (%) of each variable - microplastics. 90
Table 22: Kruskal-Wallis H test results (reading frequency/ agreement) – microplastics. 91
Table 23: Kruskal-Wallis H test results (age/probability) - microplastics. 92
Table 24: GA and TA frequency results on comprehension - microplastics. 92
Table 25: Comprehension results of question 1 - microplastics. 93
Table 26: Comprehension results of question 2 - microplastics. 93
Table 27: Crosstable GA and TA 1st impression - seahorse. 95
Table 28: Frequency of engagement and interaction variables TA section - seahorse. 96
Table 29: Frequency of engagement and interaction variables GA section - seahorse. 96
Table 30: Significance of the differences between GA and TA in engagement and interaction variables - seahorse. 98
Table 31: Increase (%) of each variable - seahorse. 99
Table 32: Kruskal-Wallis H test results (frequency of reading/ agreement) – seahorse. 99

Table 33: Kruskal-Wallis H test results (age/probability) - seahorse. 100
Table 34: GA and TA frequency results on comprehension - seahorse. 101
Table 35: Comprehension results of question 1 - seahorse. 101
Table 36: Comprehension results of question 2 - seahorse. 102
Table 37: Interest influence on key variables. 105
Table 38: Descriptive results GA representation - experts. 107
Table 39: Descriptives results inclusion in future articles - experts. 107

List of Charts

Chart 1: Frequency of age group results. 68
Chart 2: Frequency of gender results. 68
Chart 3: Frequency of qualifications results. 69
Chart 4: Frequency of reading frequency results. 71
Chart 5: Motives to read scientific articles. 72
Chart 6: Frequency of science communication results. 73
Chart 7: Frequency of expert-only articles results. 73
Chart 8: Frequency of 1st impression categories GA and TA – *anisakis*. 75
Chart 9: Frequency of 1st impression categories GA and TA – microplastics. 85
Chart 10: Frequency of first impression categories GA and TA - seahorse. 94

List of Figures

Figure 1: Differences between research today and research in the future based on Science 2.0 guideline. Adapt from: Bartling, S.F. 10
Figure 2: On the left, there is an example of cave art that represents the act of hunting, an essential activity for pre-historic humans (Credit: adobe stock). In the middle, there is an illustration present in an Egyptian manuscript (Credit: adobe stock). On the right, there is an illustration of cork seen at the microscope, present in Micrographia, by Robert Hooke (Credit: Wellcome Collection. CC. BY) 19
Figure 3: Examples of each type of GAs here considering. Each image represent: a) The classic diagram; b) the p-value, c) infographic, d) the comic strip. Credit: Animate your science. 25
Figure 4: Components of an effective graphical abstract. GA developed by Animate Your Science about the article " Ibrahim, A.M., et al., Visual Abstracts to Disseminate Research on Social Media. Annals of Surgery, 2017. 266(6): p. E46-E48. “. 28
Figure 5: Gestalt theory - visual perception principles. Adapted from: toptal.com. 29
Figure 6: Physical characteristics of colour: a) colour wheel; b) colour harmony; c) colour properties. Adapted from: #EstudoEmCasa – República Portuguesa and Procriativo Agência Multimídia. 30
Figure 7: Colour psychology. Adapted from: Procriativo Agência Multimídia. 31
Figure 8: Grid anatomy. Adapted from: studypool.com 32
Figure 9: Grid systems. a) manuscript grid symmetrical; b) manuscript grid asymmetrical; c) symmetrical grid (single-column); d) symmetrical grid (double-column); e) symmetrical grid (multi-column); f) modular grid; g) modular grid with spatial zones; h) asymmetrical columnar grid; i) asymmetrical modular grid; j) baseline grid; k) hierarchical grid. Adapted from: Poulin, R., Grid Systems, in Design School Layout A Practical Guide For Students And Designers 2018, Rockport Publishers: Beverly, USA. 34
Figure 10: Terminology of type 35
Figure 11: VOX-ATYPI classification system. Adapted from: lisagamerdesing.co.uk 38
Figure 12: Deductive- hypothetical model. 41
Figure 13: ABT framework. 46
Figure 14: Layout sketch. 47
Figure 15: Graphical abstract - *anisakis* article. 48
Figure 16: Essential steps of Anisakis GAI development. 49
Figure 17: Graphical abstract - microplastics article. 50
Figure 18: Essential steps of microplastics GAI development. 51
Figure 19: Graphical abstract - seahorse article. 52
Figure 20: Essential steps of seahorse GAI development. 53
Figure 21: Survey flow (^ = and; v = or; → = if^). 54

List of Abbreviations

FCUP	FACULTY OF SCIENCES OF THE UNIVERSITY OF PORTO
FBAUP	FACULTY OF FINE ARTES OF THE UNIVERSITY OF PORTO
UP	UNIVERSITY OF PORTO
GA	GRAPHICAL ABSTRACT
TA	TEXTUAL ABSTRACT
EC	EUROPEAN COMMISSION
CTML	COGNITIVE THEORY OF MULTIMEDIA LEARNING
AJN	AMERICAN JOURNAL OF NEOPHROLOGY
GAI	GRAPHICAL ABSTRACT IN INFOGRAPHIC STYLE

Chapter 1: Introduction

1. Summary

In the context of this introductory chapter, our primary aim lies in providing the background relevant to this dissertation, as well as presenting its fundamental objectives and motivations. To achieve this, we begin with a brief discussion of the increasing role of scientific communication in connecting research and the general public. Subsequently, we describe the motivation and objectives intrinsically related to this dissertation.

1.1. Background

Ever since humankind became conscious, knowledge has been created through a diverse array of means. Without delving into how it was and is created, what is certain is that it is only relevant if it is spread (Merton, 1993). In prehistoric times, knowledge was transmitted orally or through practical demonstrations. Despite the predominantly unrecorded nature of knowledge from this period (Bartling, 2014), basic daily activities were described much like they are today, indicating that, in some way, they still reached their intended audience. The writing system came to initiate a revolution in the way knowledge is transmitted, building up to knowledge being both professionalized and institutionalized. This transformed it into well-structured and organized disciplines that engaged the thoughts of philosophers and creative minds – the scientists. Nevertheless, technical innovation was not the sole contributor to achieving the modern science we know today. For centuries, social and historical contexts have played a significant role in shaping the evolution of knowledge transmission, a phenomenon that continues to hold true today (Bartling, 2014).

Since the time of the first scientific revolution in the 17^{th} century, when science became a profession, the cornerstone of knowledge transmission - now commonly referred to as science communication - is the journal publication system. This restrictive and well-organized structure of formalizing scientific research beyond the confines of laboratory walls has remained nearly unchanged since its inception (Ranford et al., 2023). Nonetheless, in the contemporary landscape, a variety of methods exist to complement and support the original publication of a study. Yet, a critical question persists: has science communication adapted well enough?

In contrast to the unchanging nature of scientific publication, modern society has undergone substantial deviations from its state in the 17^{th} century (Bartling, 2014). This underscores the demanding challenge faced by science communication to adapt (Jucan

& Jucan, 2014). As the internet and technology started to arise, access to information gets easier every day. While the population has become more cognizant of existing issues, it has also become more vulnerable to misinformation. The vast volume of available information today presents an overwhelming challenge, rendering it increasingly difficult to ascertain the reliability of a given piece of information. Faced with such a vast amount of available information, the public experiences frustration and diminishing interest in comprehending the world around him (D., 2015). To overcome this, it is imperative to devise strategies that not only deliver reliable information but also engage the main audience’s interest. There is a diverse range of strategies that can be employed to address this. In the present study, we approach from the basics.

Currently, scientific articles remain among the most reliable sources of information crafted by scientists. Despite the increasing accessibility, the truth is that scientific articles are not tailored for non-experts, often characterized by a formal structure and speech that distance itself from the public (Parés, 2023). Hereupon, the graphical abstract (GA) became known. First introduced by Elsevier in 2014, the GA tends to bridge the gap between academia and the general public. It achieves this by transforming the scientific article into a more engaging element for the non-expert audience without altering the main structure of the article. In addition, the GA provides an opportunity to visually share a fundamental element of the article – the abstract - through new and trending communication channels, such as social media, which are widely used by the general public (Yoon & Chung, 2017).

In a world where visual communication plays an ever-increasing role, this study focuses on the incorporation of GAs into scientific articles and attempts to evaluate their potential impact on the broader audience’s understanding and engagement with science.

1.2. Dissertation motivation

In the preceding years, global society experienced a profound and traumatic event – the COVID-19 pandemic – that has left lasting scars on modern society. The scientific community faced a serious challenge in justifying the restrictive measures implemented by government entities. More than ever, it was imperative to communicate science to the general public, as millions of lives depended on it. This event has permanently transformed science communication, highlighting the critical importance of ensuring that society is scientifically informed (Hotez, 2022). The COVID-19 pandemic came to impulse an already growing field. Motivated to inform decision-makers; build public trust in the institutions, address misinformation; and enhance global challenges and solutions; science communicators have been creating innovative and creative techniques (Kappel & Holmen, 2019).

As previously mentioned, the GA is one of these novel techniques. When first introduced, the GA was conceived as a browsing tool, facilitating scientists in efficiently filtering information within an article to determine its relevance to their research. During this early stage, GAs mainly consisted of simple images or graphics presenting the key findings of a study (Yoon & Chung, 2017). Nowadays, there is a diverse array of GA types, some tailored for expert audiences and others designed for the non-expert public (Rossi, 2017). Recently, some scientific journals have embraced sharing GAs on social media, reporting unexpectedly high user interactions (Ibrahim et al., 2017). Nevertheless, there remains a shortage of research assessing the true impact of GAs on non-expert audiences. The question of whether the additional costs and efforts associated with integrating GAs into scientific articles (Yoon & Chung, 2017) are outweighed by their effective engagement with the general public remains unanswered. These topics together comprise the problem we want to address.

Additionally, author Mariana Campos has a personal motivation. Throughout the years of the pandemic, I directly experienced the scientific challenge of informing the population in a manner that would enable them to make informed decisions. Having both of my parents working in the health system and my sister engaged in biological research, I became strongly aware of the significant gap that exists in achieving a scientifically informed society. This realization sparked a desire within me to contribute meaningfully to this issue. Combined with my interest in communication design, the idea explored in this dissertation emerged as an effort to innovate, even in a modest capacity, the way science is communicated.

The paramount significance of innovating science communication, the urge to develop more effective methods for connecting science with the non-expert public, the existing research gap concerning the impact of GAs on this audience and my interest in the topic, comprise the motivation inherent in this study.

1.3. Dissertation objectives

Considering the aforementioned, this dissertation seeks to address the growing need for the effective communication of clear and correct scientific information to the non-expert public. It does so by exploring the potential of GAs, as an effective tool to engage this vast audience, boost their interest and improve their level of understanding.

On this premise, our primary goal is to assess the true potential of GAs, when referring to a non-expert audience. By considering both their benefits and limitations, we hope to determine whether introducing GAs as a component of scientific articles represents an advantage in science communication. Therefore, our objectives comprise:

- a deep description of the current state-of-the-art process of scientific research, with a specific focus on its final step: the disclosure of the research findings. In this context, we address the topics of science dissemination and science communication. Following our investigation, it is imperative to extensively examine the historical evolution and contemporary state-of-the-art concerning the GA.
- a comprehensive analysis of the methodology employed in this project: survey research was undertaken to ensure that the development and analysis of our elements meet the expected directives, resulting in a valid and reliable study. Specifically, this includes:
    1. the development of a survey instrument, which focuses on assessing the potential of GAs to enhance interest, comprehension and engagement among non-expert audiences when compared to the traditional textual abstract (TA).
    2. designing GAs to be included as a fundamental section in the previous survey.
    3. applying the survey to a broader audience, and thoroughly analysing the results.

To complement our primary goal, we intend to augment our findings by incorporating expert perspectives on science communication, with a specific focus on GAs. Given that GAs are incorporated into the primary work of experts, namely scientific articles, it becomes imperative to acknowledge the expert’s standpoint regarding their integration. As such, our objectives also include:

- the development of a survey section, for experts only, which intends to assess experts’ general perspectives on key topics in science communication, and in particular on key topics concerning GAs.
- analyse these results.

Chapter 2: State of the art

2.1. Disclosure of science

In this section, we aim to provide an in-depth description of the current trends concerning scientific communication and dissemination, tracing their evolution to their present state. Our approach begins by contextualizing scientific communication within the broader landscape of scientific research. We then proceed to define and distinguish between science dissemination and science communication, delving into their current tendencies and channels.

2.1.1. Scientific research

The foundation of modern society rests on the ongoing accumulation of new information. In turn, this information is generated by extensive scientific research worldwide. Scientific research is a systematic approach to gaining knowledge intended to solve a pre-existing problem or address a specific question (Çaparlar & Dönmez, 2016). Even so, while the outcomes and conclusions of the research can hold significant implications for the subject under investigation, their real impact often hinges on how effectively this is spread to the relevant audience. (Fischhoff & Scheufele, 2013)

Science operates through the active collaboration of various stakeholders, including researchers, government leaders and the general public. Beyond promoting communication among research groups, scientific findings play a determinant role in shaping political decisions, addressing social challenges, and guiding legislative actions for the benefit of the public welfare. Regarding the general public, its acceptance and understanding of scientific knowledge is essential not only in creating informed and aware societies but also in ensuring the necessary support and funding for sustained scientific research (Goodman & Thompson, 2017; Trust, 2000).

To maximize the impact of research findings, it is critical to implement effective strategies and methods that bring the discovery closer to its audience (Cooke et al., 2017). The variety of strategies and methods available constitutes what is now known as science communication and science dissemination. However, sometimes it is challenging to establish a clear distinction between these terms (Gimeno, 2018). That is why, in the following section, we will be analysing these concepts and understanding the differences between them.

2.1.2 Science dissemination vs science communication

Working as the cornerstone of modern knowledge exchange, science dissemination and science communication share the common goal of promoting scientific literacy and engagement with science. However, they diverge in their approaches and methodologies. Hereupon, the European Commission (EC) first included in the Horizon 2020 programme (Commission, 2014b), the clarification of each one of these terms, focusing on their similarities and differences. This topic continues to be relevant in the latest Horizon European programme (Commission, 2023).

According to the EC, science dissemination embodies the process of sharing scientific findings, discoveries, and insights with broader audiences beyond the research groups (Gimeno, 2018). It encompasses traditional channels of knowledge transmission, such as scientific articles, conferences, and databases. It is targeted to scientists, but not only. Authorities, industry, policymakers, and others can learn from the results published. Hence, the EC recommends that the dissemination takes place as soon as the research/action has significant results. This allows maximizing the research impact, making it possible for others to take insights from these results and apply them to their related research. At the same time, the state of the art on this matter advances, adding knowledge and understanding to the field (Commission, 2014a).

On the other hand, the EC characterises science communication as a multifaceted attempt to extend research and its results beyond the mere dissemination of the information to encompass the art of engaging, informing and inspiring audiences with the wonders of science (Commission, 2014b). It involves having a well-designed strategic crafting and delivery of clear messages through the right media channels and formats, tailored to the needs, interests, and comprehension levels of specific target audiences. Communication promotes research and its results, which allows attracting the best experts to a research team, engages with stakeholders, generates market demand and ultimately raises awareness of how public money is spent (Commission, 2014a).

Table 1 summarizes the differences between these terms considering the objectives, audience, language, and channels.

Nowadays, the impact of scientific research is strongly dependent on communication and dissemination; in such a way that the EC includes legal obligations of communicating and disseminating results in all assigned research grant contracts (Commission, 2014a). By imposing these requirements, the EC ensures that research funded by them has a greater impact both within the scientific community and among the general public (Commission, 2014b). From the researcher's perspective, however, it represents an additional burden beyond the research itself (Besley et al., 2018). Given the significant role of science communication in the advancement of science, efforts must be directed towards optimizing both activities, such as integrating them to work synergistically. Understanding the models of science communication and embracing open science, a concept widely discussed today, represents the initial steps towards achieving this goal, driving science into a new era often referred to as Science 2.0 (Bartling, 2014). We will delve deeper into this topic in the following chapter.

Table 1: Differences between Science dissemination and science communication. Adapted from: Gimeno, C., Communication vs Dissemination: What is the difference, I.h.E. Commission, Editor. 2018.

	SCIENCE DISSEMINATION	SCIENCE COMMUNICATION
OBJETIVES	Public disclosure of results	Promotion of the project and its results
AUDIENCE	Target groups (scientifc communities, industry stakeholders, policy-makers)	General public, civil society and mass media
LANGUAGE	Scientific language	Non-specialised language
CHANNELS	Peer-review jornals, scientific conferences, online repository of results	TV channels, radio, newspapers, generalist website, newsletters

2.1.2. Models of science communication

Before introducing science 2.0, it is important to explain the basis that built science communication theory. The theory behind science communication is typically characterized by three different models of communication: the deficit model, the contextual model, and the participation model (Bucchi, 2008).

The deficit model assumes that the public's lack of confidence towards science is caused by the public insufficient scientific knowledge. In this approach, scientists try to oppose this "deficit" by sharing their concerns and findings with the public. Here the transfer of knowledge is one-way (specialists → non-specialists) and top-down (knowledge carrier → lay people) (Miller, 2001; Wynne, 1991). This model emerged during the posterior period of the Second World War. Around the 1950s, decision-makers and educators realized the importance of having scientifically literate citizens, to understand scientific principles, research processes, and the role of science in society. Likewise, the public will be able to make informed decisions about quick developments in science and technology (DeBoer, 2000; Miller, 1998).

The contextual model is a complement to the previous one. Here, the objective is also to get information out to the public. In other words, the specialists are aware of the needs, attitudes, and pre-existing knowledge of the public, adjusting their content depending on it. Considering questions such as “What does my audience already know about this topic?” or “Why does my audience need this information?” may be important to choose the right communication approach (Miller, 2001).

On the other hand, the participation model integrates scientists, the public, and policymakers in discussions and debates about issues in science and technology. These may occur in a variety of formats, such as conferences and public forums. With this model the scientist takes advantage of the interest of the public, making it possible to integrate the public into scientific research (Trench, 2008). Activities based on the participation model encourage members of the public to learn about a scientific topic and its implications for society. Citizen science, a type of research where the public has an active role either in the collection of data or in another step of the research, is based on this communication model (Wilsdon, 2004).

2.1.3. The new science: Science 2.0

After the first scientific revolution back in the 17th century, some academics argue that we are now on the brink of the second (Bartling, 2014). While the process of conducting science has remained unchanged, the methods of transmitting knowledge are undergoing a profound transformation. The Internet, in particular, has had a monumental impact on modern society, revolutionizing the dissemination of information. As a result, the second scientific revolution is built upon two central concepts: open science and science 2.0 (Bartling, 2014; Fiore, 2012).

It can be argued that science has always been open, as open as the methods and cultural norms of the time allowed (Bartling, 2014). However, the concept of “Open Science” emphasizes connectivity and collaboration. Open science has introduced tools, platforms, and methods that have irreversibly changed the way research is designed, performed, captured, and evaluated. According to a study conducted by the University of Valencia, Open Science is “the transparent and accessible knowledge that is shared and developed through collaborative networks". The authors assert that open science is of utmost importance in addressing the challenges that humanity faces in the 21st century.

On the other hand, achieving greater openness in science requires widespread dissemination of information, motivating scientists to discuss Science 2.0. In contrast to Science 1.0, where the scientific culture did not fully leverage the internet (Bartling, 2014), Science 2.0 involves new practices where scientists share raw experimental results, emergent theories, claims of discovery and draft papers on the web for others to view and engage with (Waldrop, 2008). Despite the advancements of Science 2.0, there remains resistance within the scientific community to share scientific information outside of traditional and official scientific platforms (D., 2015).

Sönke Bartling and Sascha Friesike advocate for an expanded online presence of science highlighting its potential benefits. Nowadays, findings are typically made public when they are positive or relevant. Consequently, the efforts expended over years of research to achieve positive results often go unrecognized and underutilized within the confines of research institutions. Bartling and Friesike propose that if scientists had the opportunity to publish their results as they occur, there would be no need to wait until the results are complete. Furthermore, even if projects were to be stopped, negative or small findings could still be published, thereby contributing to the scientific knowledge process. The only concern highlighted by Bartling and Friesike is the need to ensure that researchers will continue to receive proper credit for their contributions (Bartling, 2014; Vicente-Saez & Martinez-Fuentes, 2018). Integrating Science 2.0 on a large scale would thus represent a significant transformation in scientific culture and the research steps (Waldrop, 2008). Figure 1 resumes the differences between research today and research in the future according to Science 2.0 guidelines.

Science 2.0 has the clear potential to boost science dissemination/communication inside and outside of the scientific community. Furthermore, online platforms play a pivotal role in making information more accessible, thereby enhancing science communication efforts (Hetland, 2011; Vicente-Saez & Martinez-Fuentes, 2018). This strengthens the relationship between the scientific community and the general public, a relationship that holds paramount significance in contemporary times (Waldrop, 2008). Of all online platforms known today, social media are undoubtedly the ones with better tools to engage and boost science communication (Agency, 2023). Considering this, in the next section we will explore how social media integrates in science 2.0 and the strategies and thoughts of science communicators towards them.

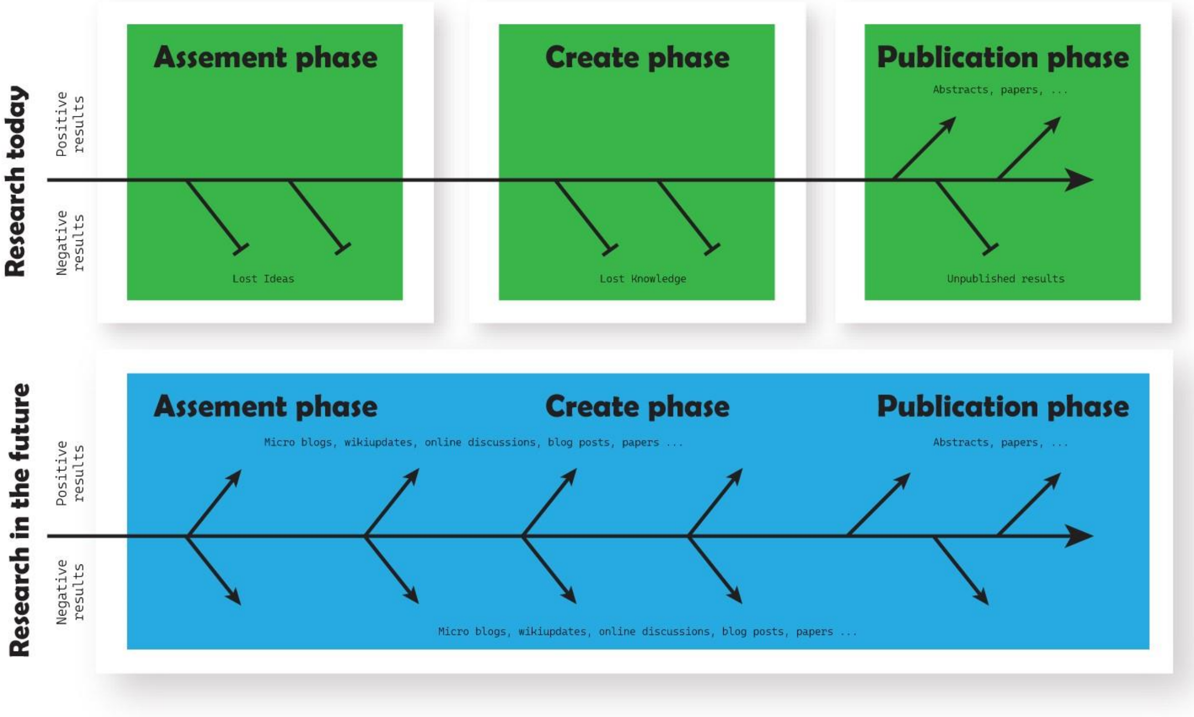


Figure 1: Differences between research today and research in the future based on Science 2.0 guideline. Adapt from: Bartling, S.F.

2.1.3.1. The role of social media in Science 2.0

As of January 2019, there were around 7.7 billion people in the world, of which 3.397 billion were active social media users. Every ten seconds, a new user joins a social media platform, further expanding its potential audience base (Agency, 2023; Rogers, 2019). In addition to its vast user base, social media platforms serve as invaluable sources for learning and knowledge-sharing (Agency, 2023). As Egoitz Pomares, director of the GI-NI project, highlights, social media's key theme is engagement, presenting unparalleled opportunities for individuals and organizations to connect with a diverse range of interested partners, and at the same time enhancing the visibility for projects and initiatives (Agency, 2023; Rogers, 2019).

The role of social media in modern communication has become increasingly prominent in recent years, prompting numerous studies to examine the dynamics and algorithms behind social media platforms. In March 2018, the Pew Research Center released a report titled "The Science people see on social media" which analysed the posts of thirty science-related pages on *Facebook* over six months. The findings of this study provided compelling evidence in favour of using social media in science communication. The results indicate that millions of people follow science-related pages on Facebook, including multiplatform organizations such as National Geographic or Discovery, as well as “Facebook primary” pages managed by individuals or smaller organizations. This highlights how social media changed the media landscape, as it has become easier and more cost-effective for entities with limited resources to disseminate scientific content to a wider audience. An example is IFLScience: The Lighter Side of Science, created in 2012 by a single enterprising writer, which amassed 25,6 million followers by 2018 and expanded to a team of fifteen employees in only four years. Furthermore, the study identified common types of posts on these science-related Facebook pages, namely “Discoveries” (29%); “News you can use”, which provides practical applications of science (21%); “Promotions and advertising” (16%); “Explanations of concepts” (12%). The report also notes a significant increase in the volume of posts from these pages over the years, along with a rise in user interactions per post – a common indicator of audience engagement based on the total number of shares, comments and likes (or other reactions). This suggests both an increase in the availability and accessibility of information and a heightened interest from the public. Moreover, posts with higher engagement levels were typically focused on visuals with minimal additional information, regardless of the post type (Olmstead;, 2018).

As had been reported, examples of how social media have enabled and eased science communication and collaboration abound, but still many scientists remain reluctant to embrace the various channels provided by social media, either out of concerns with time or resources or due to trust issues with these platforms (Hunter, 2020). In the scientific community, social media are perceived as informal or lacking professionalism compared to traditional academic channels. As a result, some scientists may be concerned about maintaining the credibility of their research and believe that sharing on social media could diminish their professional reputation (Hammer, 2017). These concerns are entirely valid, particularly in today´s digital landscape rife with misinformation. Social media platforms, in particular, are notorious for rapidly disseminating and amplifying fake news (Baptista & Gradim, 2020). In light of this, it is crucial to focus the efforts not on avoiding social media sharing altogether but on ensuring that information is accurately transmitted and shared through channels deemed trustworthy by the general public (Hammer, 2017; Hunter, 2020).

2.2. Communication theory

In the present section, our objective is to provide a comprehensive overview of the theory behind effective communication. We will explore various types of communication and the diverse range of learning styles, with a particular focus on their application to science communication. Building on the data supporting the role of visual communication, especially in the context of science communication, we will conclude the topic with a historical perspective on the importance of images in science publication and communication.

2.2.1. Effective communication

Science is all around us in every aspect of modern life. As a result, individuals are increasingly required to blend scientific information with their values and additional factors when making crucial life decisions. These may be about deciding to vaccinate their children, ensuring the safety of food products, or addressing climate change (National Academies of Sciences, 2017). As a result, science communication becomes a need more than an extra work field. The EC Special Eurobarometer 282 named "Scientific research in the media" concluded that the average level of public interest in scientific research is 57% (13% answered "very interested" and 44% answered "fairly interested" to the question "Would you say that you are (…) in scientific research"). In Portugal, the percentage decreases to 42%. Also, when asked the question "In general, are you *[answer]* with the way the media provide information about scientific research?" 56% of the public says they are not satisfied ("not very satisfied" together with "not at all satisfied") and 4% answers "I don´t know" (Commission, 2007). Complementary, in the EC Special Eurobarometer 516 the public reveals a strong intention to learn more about scientific developments (54% strongly agree or tend to agree with the statement "I would like to learn more about scientific developments."). Even so, in the EU, 46% of the population agrees with the statement, "Science is so complicated that I do not understand much about it". Portugal reveals interesting results because while 80% of the population shows interest in learning more about scientific research, only 28% disagree with the previous statement related to the complexity of science (Commission, 2021). This data highlight the imperative need to enhance the effectiveness of science communication by innovating the delivery of scientific information through the media, ensuring it is both engaging and comprehensible to the public.

Both the traditional and the emergent channels for disseminating scientific knowledge have their strengths and weaknesses to achieve the changes needed.

However, each channel is more suitable for specific objectives. Faced with a non-expert audience, whose minds may not be trained to evaluate the information critically, it is imperative to ensure that the information is trustworthy, accurate, and effectively transmits the intended message. This is essential to prevent misinterpretation and to stimulate the interest of the non-specialist public in the topics at hand. While effective communication is also important for specialists, they typically possess the tools and background knowledge to understand and evaluate the information more critically (Fischhoff, 2013; J.E. Thomas, 2006; Jucan & Jucan, 2014).

Taking the above into consideration, it is evident that communication strategies must be tailored to the specific needs and backgrounds of different audience groups. Therefore, when communicating science to a broader audience, it is not only essential to select the proper channels but also to understand which types of communication are most effective for our target audience (National Academies of Sciences, 2017). Although individual preferences may vary, societal norms and preferences tend to shape overarching communication trends, highlighting certain types of communication as more prevalent and effective (J.E. Thomas, 2006). This leads us to the question: What are the different types of communication? And which ones are most suitable for reaching each target audience? In the following section, we will delve deeper into these concepts, and endeavour to answer these questions.

2.2.2. Types of communication

Effective communication is essential in both personal and professional matters. Understanding the different forms of communication can enhance our ability to connect with others, convey our messages effectively, and navigate the complexities of human interaction behind business and education (Cooke et al., 2017). From verbal and nonverbal communication to written and visual communication, each type has its unique characteristics and applications. Ensuring that the appropriate form of communication is used is fundamental for aligning with the objectives defined in each communication field, especially in science communication (Cooke et al., 2017; McQuail, 2003).

Communication theory is a relevant area within the social sciences and its relevance expands to science through science communication. A comprehensive grasp of the various communication types is vital for effectively engaging the public with scientific concepts. Typically, specialists recognize 4 primary communication types: verbal, non-verbal, written and visual communication (McQuail, 2003).

2.2.2.1 Verbal and non-verbal communication

Verbal communication is the act of speaking with others. It can occur face-to-face, via telephone, *Zoom* and other platforms (McQuail, 2003). In science communication, verbal communication involves the use of spoken words to convey scientific information in a clear, engaging, and understandable way. Effective verbal communication in science uses accessible language, avoiding technical terms whenever possible. At the same time, storytelling techniques are essential to making complex scientific concepts more relatable and memorable to the audience (Chan, 2011). Nowadays, the growing popularity of podcasts, namely science podcasts is the peak of verbal communication. Podcasts are distributed to the public using online platforms and are particularly convenient for their audience as they can be listened to while undertaking other activities, which is therefore very attractive (Vainieri, 2023). Side by side appears non-verbal communication which exists by itself, and also as a complement to verbal communication. Non-verbal communication includes facial expressions, posture, eye contact, hand movements or touch. This can significantly impact how scientific information is perceived and understood by the audience. For example, using eye contact and open body language can help establish trust with the audience, while monotone voices or nervous gestures may convey disinterest or lack of confidence (Hall et al., 2019). By combining clear and engaging verbal communication with positive nonverbal cues, science communication can effectively convey complex scientific information and inspire curiosity and interest in the audience (McQuail, 2003). In contemporary times, the downside of these types of communication is the significant time investment required from the audience. Whether engaging with podcasts, presentations or interviews, the individuals must allocate substantial time and concentration to absorb the content effectively. Given the declining attention spans of the general public, many may approach such content with apprehension due to the perceived time commitment involved (Subramanian, 2018).

2.2.2.2 Written communication

Written communication encompasses any written messages exchanged between two or more individuals (McQuail, 2003). While typically more formal, it can take various forms such as emails, reports, articles, Facebook posts and tweets. Written communication is integral to science communication and dissemination, particularly in scientific articles. This type of communication allows for careful crafting of messages, providing detailed explanations and supporting evidence to enhance understanding. However, these written materials often only target specialized audiences, missing opportunities to engage with the general public effectively. Language barriers, overuse of technical terms, and information overload can also hinder communication efforts (Milinovich, 2009). Furthermore, there is a growing tendency of declining interest in writing communication among the public, mainly caused by the attention span shrinking, highlighting the need for innovation in science communication strategies (Subramanian, 2018).

2.2.2.3 Visual communication

As the name suggests, visual communication involves conveying messages through visual representations, such as signs, icons, typography, drawings, and graphic designs, among others. This mode of communication relies on the sense of vision and explores the idea that a visual message accompanying text has a greater power to inform, educate or persuade than text alone ("Introduction to Visual Communication," 2014; J.E. Thomas, 2006; Yoon & Chung, 2017). In 1986, Allan Paivio studied the cognitive subsystems, discovering that verbal and non-verbal communication are processed in two separate cognitive subsystems. Following this theory, in 2005, Richard Mayer developed the cognitive theory of multimedia learning (CTML). According to this theory, text and visual information enter the mind through sensory memory and are processed through selection, organization, and integration. Firstly, relevant words and images are selected from the given material. Then, in the organization process, these form coherent verbal and/or visual representations. Selection and organization processes are conducted in two separate channels inside the working memory. Finally, the representations created are integrated with previous knowledge retrieved from long-term memory. Both of these theories support the potential of multimodal information (Yoon & Chung, 2017). Beyond that, this research findings indicate that individuals tend to process visual information at a faster rate compared to textual information. For instance, a study conducted by IMT revealed that intervals of image processing time ranged from 13 to 80 milliseconds, contrasting with the 250 milliseconds typically required for text processing (Potter, 2014). Furthermore, a 2011 study concluded that around 65% of the population tends to be “visual learners”, indicating a preference for understanding information through visual representation (Bradford, 2011). Additionally, visuals can evoke emotions enhancing storytelling, thus facilitating message transmission ("Introduction to Visual Communication," 2014; J.E. Thomas, 2006).

In science, visual communication plays a crucial role in simplifying complex ideas and data, making them clear and accessible to a broader audience. Infographics, diagrams, photographs, maps, graphics, tables, and posters are some examples of visual aids commonly used in scientific communication (J.E. Thomas, 2006). In recent years, advancements in digital technologies have expanded the possibilities and demands of visual communication in science, contributing to more effective science communication. However, despite the significance of visual communication, many researchers lack the resources, expertise, and time to create well-designed visuals that effectively convey their findings (Franconeri et al., 2021). As a result, there is a need for more research that evaluates the real impact of visuals in science communication. This research field can inform stakeholders in science magazines or research centres about the importance of employing skilled professionals, such as science communicators or graphic designers, to develop visuals that maximize the impact of scientific discoveries (J.E. Thomas, 2006). Given the prevailing tendencies and social preferences, visual communication emerges as a potent force in enhancing science communication. However, as explained in the subsequent section, visuals have played a major role throughout the evolution of science (Evagorou et al., 2015).

2.2.3. Visuals in science history

Across the timeline of human evolution, images and visuals have held paramount importance as a primary medium for conveying information. Concerning scientific endeavours, this mode of communication has evolved significantly since then, reflecting advancements in technology, changes in scientific methodologies and shifts in communication practices (Palmedo, 2020).

The first visual representation related to science is considered to be cave art. Cave art is an ancient form of communication, driven by observation of the natural world [Figure 2 – Left]. Our ancestors were faced with an unbalanced, chaotic natural work, which they had to face deciphering the regularities and patterns in nature that had a higher probability of survival. The cave paintings allowed this discovery and observation to prevail for posterior individuals (Hodgson, 2019; Palmedo, 2020). Centuries later, in ancient civilizations such as Mesopotamia, Egypt and Greece, scientific manuscripts often featured hand-drawn illustrations and diagrams depicting natural phenomena, anatomical structures, and astronomical observations [Figure 2 – Center]. These were intended to accompany written descriptions of scientific concepts. During medieval times, historians say that these pictures were especially important because many people, even those who owned manuscripts, could not read (Da Rold, 2020).

The Renaissance period, motivated by the increasing interest and development of science, was observed as an improvement of these illustrations, being here the period of origin of scientific illustration. At this time, artists specialized in producing detailed and accurate drawings of plants, animals, anatomical specimens, experimental apparatuses and observed phenomena (Mack, 2015). Being an abundant period of scientific discoveries and considering the low level of globalization at the time, these illustrations played a crucial role in documenting scientific discoveries and disseminating knowledge among academics. Examples are taxonomically distinction through faith reproduction of diagnostic characteristics (Hodges, 2003); or in *Micrographia* by Robert Hooke in 1665 where a central concept in Life Sciences was revealed and disseminated – the cell [Figure 2 – Right].

In the 19th century, illustrations transformed into photographs, either real, macro, or micro size. The development of amplifying tools and the improvement of photography techniques allowed to capture precise images of specimens, experiments, or phenomena with unprecedented accuracy and detail. This helped to corroborate many hypotheses and disseminate novel concepts (Hodges, 2003). As scientific data increases in complexity, visualization techniques have become essential for interpreting and communicating research findings. Charts, maps, graphics, and 3D models are examples of a variety of visual representations of data used by scientists (Evagorou et al., 2015). Nowadays, visual elements take a prominent role in our culture, identity, and knowledge, especially in contemporary sharing societies. By allowing an in-depth understanding of highly complex matters and scientific findings, they are not only contributing to better scientific dissemination but also to improving science communication to non-specialist audiences (Estrada R, 2014; Franconeri et al., 2021).

Taking the previous into account, specialists are looking for innovative strategies and data representations to achieve better outcomes on science communication actions related to their research. Keeping their work trustworthy and scientifically accurate are key points to ensure when trying to develop these visual representations (Franconeri et al., 2021). Throughout the years different ideas emerged, for example: infographics, interactive visualizations, virtual reality experiences and animated visualizations (Kelleher & Wagener, 2011). Each one of these has its advantages and disadvantages, although a recent type of visual representation has revealed a greater potential even if its impact is not fully understood. These are **graphical abstracts (GAs)**.

Figure 2: On the left, there is an example of cave art that represents the act of hunting, an essential activity for pre-historic humans (Credit: adobe stock). In the middle, there is an illustration present in an Egyptian manuscript (Credit: adobe stock). On the right, there is an illustration of cork seen at the microscope, present in Micrographia, by Robert Hooke (Credit: Wellcome Collection. CC. BY)

2.3. Graphical abstracts

Within the present section, we seek to extensively explore the concept of GAs integrated into the wider field of science communication. We will cover the definition and purpose of GAs, the diverse types of GAs, and a historical perspective of its origin. Considering the practical essence of the work here being developed, we will also review the basic content and design principles important to GA design. Finally, we will refer to the limitations of GA within visual science communication.

2.3.1. Graphical Abstract

Visual information is becoming a more prevalent means of communication, mainly due to the evolution of digital technologies, that made it easier to generate and disseminate science (Yoon & Chung, 2017). As reviewed in the previous section, visualization has an increasing potential to attract public communities. Visualization is a graphical representation of data, information and/or knowledge. Its objective is to convey and communicate information, thus amplifying cognition. In science dissemination and communication, it is typically to see visual representations of scientific research in scientific posters or conference presentations, contributing to the engagement of the audience to the scientific topic (Nikolian & Ibrahim, 2017; Yoon & Chung, 2017).

Additionally, journal articles usually integrate visual information, such as tables, graphics, and photos, to effectively present results and to show models, examples, and contextual backgrounds within scholarly communications (Yoon & Chung, 2017). Recently, the GA has marked its presence in the field of visual science communication. The GA is intended to expand the impact of scientific articles, transforming a required element of scientific research into a powerful tool for science communication. As an integral part of scientific articles, GA can boost science communication by taking advantage of the trust and scientific coherence the specialists and non-specialists attribute to scientific articles. While the impact of GA on non-specialist audiences is not totally understood, some studies revealed that GA has been shown to improve the reach of new scientific publications (Evagorou et al., 2015; Parés, 2023). In 2017, Andrew Ibrahim and his research team at Michigan University conducted a study where they used Twitter to quantify the impact of including a GA in promoting new publications. The researchers compared Twitter posts with and without GA over one year, using each post as its control. They found that the reach of posts with GAs was dramatically greater than those without. Tweets with GA received a 7.7-fold increase in Twitter impressions, an 8.4-fold increase in re-tweets, and a 2.7-fold increase in article visits (Ibrahim et al., 2017). Although the authors concluded that GA was responsible for the increased dissemination, highlighting the potential of GAs, some argued that it is possible that the inclusion of any image would have produced similar results. To clarify this matter, Joel Topf conducted a prospective case-control crossover study. Forty research articles published in the American Journal of Nephrology (AJN), were shared on the AJN X account (old Twitter) in three formats: (1) the article citation; (2) the citation with a key figure from the article; and (3) the citation with a visual abstract. The results revealed that "tweets" containing a visual abstract had more than twice as many views as citation-only tweets, and twice as many views as key figure tweets. In terms of engagement, the 3rd-format had five times more engagement than the 1st-format and 3.5 times more than the 2nd-format. Finally, GA tweets were also associated with higher increases in Altmetric scores than citation-only tweets. These findings support the broader use of GAs in the scientific community. In the next section, we will lean over the definition and purpose of GA.

2.3.2. Definition and purpose

In 2013, Elsevier launched the "Article of the Future Project". Here, this important publisher in the biomedical sciences field, aimed to revolutionize the traditional format of academic papers. One of the most significant outcomes of this article is the GA. Here it was defined as an infographic that attracts potential readers and shows the results and overall achievements of the paper at a single glance (Yoon & Chung, 2017). Throughout the years this definition has evolved and today most accept that a GA is a visual summary, highlighting a scientific article's key points. Unlike traditional written abstracts, it offers the same content but in a visually engaging format that's easy to share and understand (Ibrahim, 2016).

It is just as important to clarify what a GA is not. A visual abstract cannot substitute reading the article in question. It is not possible to cover all the details of an article in a GA, as it is impossible to do so in a TA. Like the TA, the GA aims to summarize the message of the article, but the GA adds the objective to increase the speed of processing this information, as well as boost the impact of the article, with the specialist public and with the non-specialist public. Furthermore, today, it is considered that a GA should not be an image taken directly from a scientific article (Ibrahim, 2016; Rossi, 2017).

The purpose of a GA is dependent on who is reading, in other words, it is dependent on the audience of the article in question. Typically, a scientific article is targeted to a more specialized public, although in science communication all publics have to be considered, and by making scientific articles more accessible to a non-specialist public the scientific community is increasing the impact of their research. Considering this, a GA is a potential way of making effective scientific communication. From a peer's perspective, a GA becomes a promotional tool that positions a scientific paper to stand out on social media or another communication channel. Considering the rate of articles published daily (around seven thousand), it becomes difficult to read all the 250-word abstracts of the articles that seem to interest to a given research. The GA can decrease these interpretation times, working as an article filter for researchers. This can translate into more citations of the article with the GA, increasing its relevance. On the other hand, a well-designed GA allows a non-specialist audience to understand and appreciate scientific research. However, not all GA are effective for the general public, which leads to the distinct types of GA that exist. A GA can extend research beyond peers, but it has to follow a diverse range of guidelines (Ibrahim, 2016; Ibrahim et al., 2017; Rossi, 2017). Hereafter, we will delve into the different types and characteristics of each type of GA.

2.3.3 Types of graphical abstracts

As explained previously there are diverse objectives, target audiences and complexities to consider in each communication event. Certain research topics are not relevant or understandable to a non-specialist public. Similarly, technical terms may fit well in peer-to-peer communications but are confusing when communicating to the lay public. When transmitting a message to the general public, the key point is to ensure that the public understands how and why the topic impacts their life and society. Considering these different demands, it would not be appropriate to have only one type of GA ("The art of abstracts," 2011).

As far as it is concerned, the different types of GA are a recent topic in science communication. In 2016, Tullio Rossi created a company named "Animate Your Science". Animate Your Science is a company dedicated to helping scientists effectively communicate their research through video and GAs, animations, scientific graphics, and posters. Their speciality is to create engaging and visually appealing elements that simplify complex scientific concepts, making them accessible to wider audiences. Their objective is to bridge the gap between scientific research and public understanding by transforming dense academic content into compelling visual narratives. This Australian company was one of the first to explore GA as an element to boost science communication and also the one that assembled the distinct categories of GA. Nowadays, there are more companies and institutions that offer the same service as Animate Your Science, therefore resulting in distinct ways of categorizing GA. Here, for the sake of this work, we will describe and follow the categories determined by Animate Your Science (Rossi, 2016).

The base of GA categories presented here is the expert–public spectrum. Each type is positioned in this spectrum, and its position determines which characteristics the GA must have. There are four principal categories of GA described: the classic diagram, the p-value, the infographic, and the comic strip. Figure 3 illustrates an example of each one of these categories.

The classic diagram [Figure 3 – a)] is the most traditional type of GA. It is 100% developed for a specialist audience, thus positioning itself closer to the expert end of the spectrum. Typically, it does not present a background to contextualize the research, containing only the results and conclusions of the study. Additionally, this type of GA usually employs technical terms and specific visual elements. This type of GA is very common in chemistry communications as it is such a visual topic.

The p-value [Figure 3 - b)] type exactly reflects its name. A p-value is a statistic that measures the significance of a determinate result, therefore being a complex element in terms of understanding demand. This type of GA usually presents p-values in its results or other types of numerical statistics. At the same time, it includes a little more context than the classic type and adds icons and more text to accompany the visual elements making it more accessible to a non-specialist public. However, it is still closer to the expert end of the spectrum. In terms of design, these GA is characterized by the use of vertical or horizontal well-defined blocks.

The infographic style [Figure 3 – c)] (GAI) is the one which balances the best interests of both the experts and the general public, considering both scientific accuracy and communication demands. Here the most important is to transmit the scientific message, instead of emphasizing the data and the results. It is the most versatile type, being able to take different formats. It is closer to the public end of the spectrum because it includes an engaging background on the investigation; uses simple language and applies attractive and clear visuals.

Finally, the comic strip type [Figure 3 – d)] is 100% developed for the public. It takes advantage of the public interest in pop culture, humour, and art, to integrate them into storytelling with a scientific message. It might include real-world references bringing the public closer and catching their attention. It does not focus on the details of the research.

2.3.4. Historic evolution

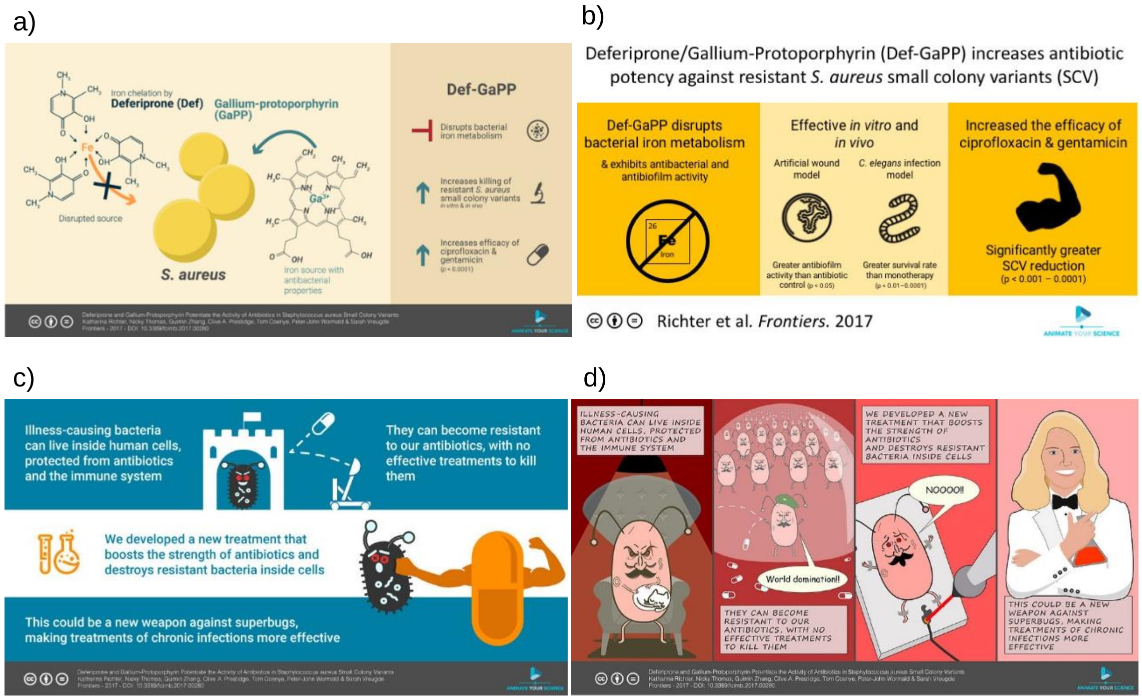


Figure 3: Examples of each type of GAs here considering. Each image represent: a) The classic diagram; b) the p-value, c) infographic, d) the comic strip. Credit: Animate your science.

Since its inception, the concept of GAs has evolved significantly. Before formalization, some advocated for using a “central illustration” or a “graphical table of contents” to disseminate the scientific work. Even though this practice dates back to the late 80’s (Ibrahim, 2017), the first reference to GAs was done by “Elsevier” in 2012. As mentioned in section 4.2, this prominent publisher in the biomedical sciences field worked on the “Article of the Future Project” between 2009 and 2011 and launched it on their web platform in 2012 (Elena Zudilova-Seinstra, 2014). The main objectives of this project were to develop updated content and new tools to support researchers in their scientific endeavours. Utilizing user-centred design approaches, Elsevier enforced the importance of visual elements and their interactivity, leading to the implementation of GAs on their web platform. The publisher conducted studies using an “eye tracking” technique to analyse readers’ visual attention patterns when reading scientific articles online. The readers were asked to find different information within an article, and the results revealed a 40% improvement in time efficiency compared to finding information on the publisher’s previous web platform. Interestingly, readers first focus on the “visual abstract” and then on the “quick access to section tool” (Elena Zudilova-Seinstra, 2014).

Although these results are promising, it is worth noting that the GAs implemented by Elsevier during this period differed from those used today to engage with non-specialized audiences (Rossi, 2016). At that time, the GAs introduced by Elsevier were primarily designed as browsing tools, aimed at helping researchers filter information more efficiently to determine the relevance of articles to their research (Elena Zudilova-Seinstra, 2014).

In 2016, the publisher Annals of Surgery pioneered using GAs as a tool for promoting research on the Internet and social media. Since then, over 100 journals and publishers have followed suit (Ibrahim et al., 2017). However, the rapid implementation of GAs resulted in substantial variability in the production process across different journals. While some entities invested in graphic designers or created formal editorial positions, others relied upon volunteers and authors to create the GAs. This results in the variable quality of these elements, which may compromise its overall impact. Additionally, some publishers made GAs a mandatory element for publication without providing authors with the proper resources or guidance for their creation. This disregards the typical lack of knowledge and ability of scientists in graphic design (Ibrahim, 2022).

Nowadays, the problem stands and despite GAs having developed from an innovative initiative at a single journal to a new tool in scientific communication, it is critical to understand how to address it. The development of any tool often follows a trajectory marked by three phases: (1) – early innovation, during which a small group of originators can safeguard high-quality results; (2) - rapid adoption, leading to variable quality due to the absence of standardization; and (3) – maturation through formal standardization and quality improvement. GAs seem firmly in the middle of this progression. Consequently, the next step involves creating guidelines to standardize the production of GAs in scientific research (Oska et al., 2020). However, achieving this goal requires overcoming significant obstacles. Firstly, an intrinsic problem like GAs compromises standardization, stemming from their wide range of types and components. Furthermore, within the scientific community, GAs are not universally recognized as essential components of scientific articles, and many fail to acknowledge their potential to engage with the general public. Furthermore, even among those who recognize their value, consensus on what constitutes a good GA, and the most suitable type of GA remains elusive, partly due to the diverse backgrounds of researchers. Since GAs' production does not align with the common scientific knowledge base, and considering the technical nature of this element, especially in the case of GAI type, creating a quality

GA poses a challenge for researchers (Ibrahim, 2017). Therefore, an important next step is to develop research that can provide data supporting the establishment of professional positions in research centres and publishers specifically dedicated to designing GAs and other visual elements (Ibrahim, 2022).

Despite the lack of standardization and concrete guidelines for designing GAs, certain principles regarding content and design aspects have been highlighted by some studies (Elena Zudilova-Seinstra, 2014; Ibrahim, 2017). In this line of thought, the next section delves into the fundamental elements of a GA concerning scientific information (content) and aesthetics (design).

2.3.5. Fundamental elements

As highlighted, when it comes to GAs there is not a one size fits all template. Scientists and artists from around the world have explored a variety of approaches and styles. While there are no concrete rules about what a GA should look like, certain components and principles are always present.

2.3.5.1. Content

The content refers to the scientific information present in the scientific article. The GA has to be based on the content of the traditional written abstract of a scientific article. A good written abstract should be structured in the following components: context/background; knowledge gap or key question(s); objective; methodology; results, conclusion; and future works. A well-done GA should also contain all these elements, although the distinction is on how the display of this information is done. Preferably, it should be a visual display such as the use of icons, and when there is a need to use text, it should be clear and short. In addition, due to the possibility of the GA being shared and disseminated apart from the article it is important to contain the article’s title, all the logos associated with the research, and the article’s citation. Finally, the GA should have a featured image, which captures the attention of the target audience. Figure 4 summarizes the essential content components in a GA.

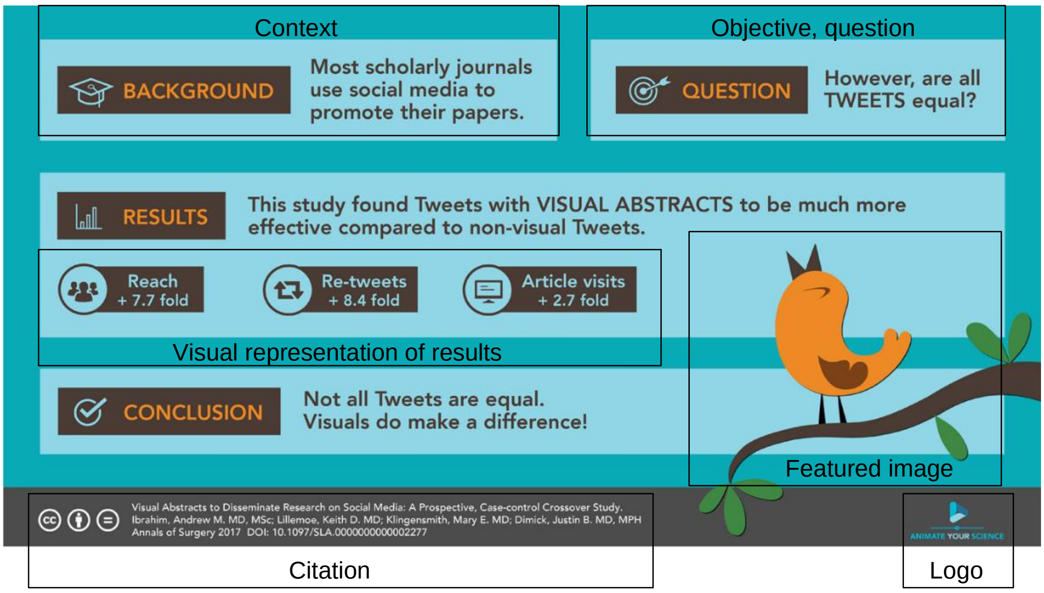


Figure 4: Components of an effective graphical abstract. GA developed by Animate Your Science about the article " Ibrahim, A.M., et al., Visual Abstracts to Disseminate Research on Social Media. Annals of Surgery, 2017. 266(6): p. E46-E48. “.

2.3.5.2. Design

When it comes to design, there is much to explore. While the content of a GA cannot extend beyond the scientific information contained in the article, its design can go far beyond it. Designing an effective GA requires understanding and applying a complex set of graphic design concepts. Therefore, before discussing the direct applications of these concepts in GAs, we will dedicate a subsection to describe some relevant design principles.

2.3.5.2.1 Design principles

I. Gestalt theory

A german word with no equivalent in English, *gestalt* means how something has been put together or arranged. *Gestalt* psychology was born out of a belief that it was essential to study things as a “whole”, instead of their constituent parts to mirror how human perception itself works. Visual perception was one of the first areas in which *Gestalt* theory was developed, and its relevance to graphic design is strong (Inglis, 2023).

There are seven key principles within *Gestalt* theory psychology that are crucial for effective design (Inglis, 2023; White, 2022):

- <u>Closure</u>: The brain is good at filling in gaps to create a whole.

- Common Fate: Objects moving in the same direction appear to belong together.
- Continuation: A line will always appear to continue travelling in the same direction
- Similarity: Two elements that share attributes will be visually grouped.
- Symmetry: The brain perceives complex objects in the simplest form possible, often interpreting ambiguous objects as symmetrical and ordered.
- Proximity: Objects that are close together will be grouped visually.
- Figure ground: Objects are perceived either in the fore or the background.

Figure 5 highlights the 7 principles underlying the Gestalt theory.

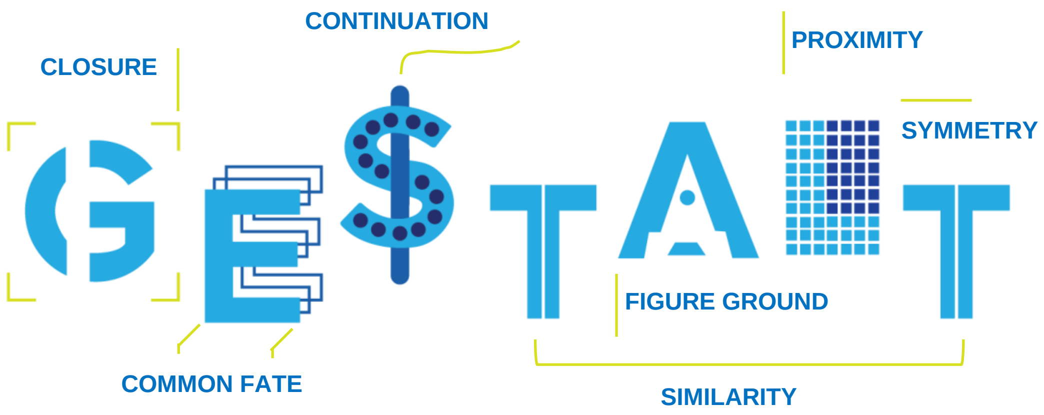


Figure 5: Gestalt theory - visual perception principles. Adapted from: toptal.com.

II. Colour theory

Colour theory is a fundamental aspect of graphic design that explores how colours interact, the visual effects of colour combinations, and the emotional responses they evoke. Colour can be used in various ways in visual communication (Inglis, 2023).

Our vision is responsible for colour perception, which is only possible due to light, particularly white light, such as sunlight. The process by which we perceive colours was discovered by Newton in 1666. He passed a ray of white light through a transparent triangular prism, thereby obtaining a range of colours that went from red to violet. These colours, called the colours of the spectrum, are the same as those seen in a rainbow. Light is part of the electromagnetic spectrum subject to be registered by the eyes, in the human case it is from red to violet (Inglis, 2023; Kuppers, 2005).

This and other experiences concerning light led to some primary concepts within the colour theory, one of them being the colour wheel. The colour wheel is a circular diagram of colours arranged by their chromatic relationship. It includes the primary colours: red, blue, and yellow, which cannot be created by mixing other colours; secondary colours: green, orange, and purple, which can be created by mixing two primary colours; tertiary colours: every other colour which is created by mixing one primary and one secondary colour (Inglis, 2023; Itten, 1997; Kuppers, 2005; Morioka, 2006).

Additionally, the colour wheel reflects other relationships between colours, particularly colour harmony. Colour harmony refers to aesthetically pleasing colour combinations based on their relationships on the colour wheel: Examples include complementary colours, analogous colours, and triadic colour combinations (Inglis, 2023; Itten, 1997; Kuppers, 2005; Morioka, 2006).

Each colour has characteristics that define it, known as colour properties. These properties are hue, value, and saturation. Hue refers to the colour itself, it is what distinguishes one colour from another. The value or tone refers to the lightness or darkness of a colour (hue). The value of a colour changes when black or white is added. Finally, saturation refers to the luminosity of a colour, describing its intensity. Furthermore, practical applications of colours such as colour temperature, colour profile, contrast, and readability, must be considered (Inglis, 2023; Itten, 1997; Kuppers, 2005; Morioka, 2006). Figure 6 summarises the physical characteristics of colour referred to above.

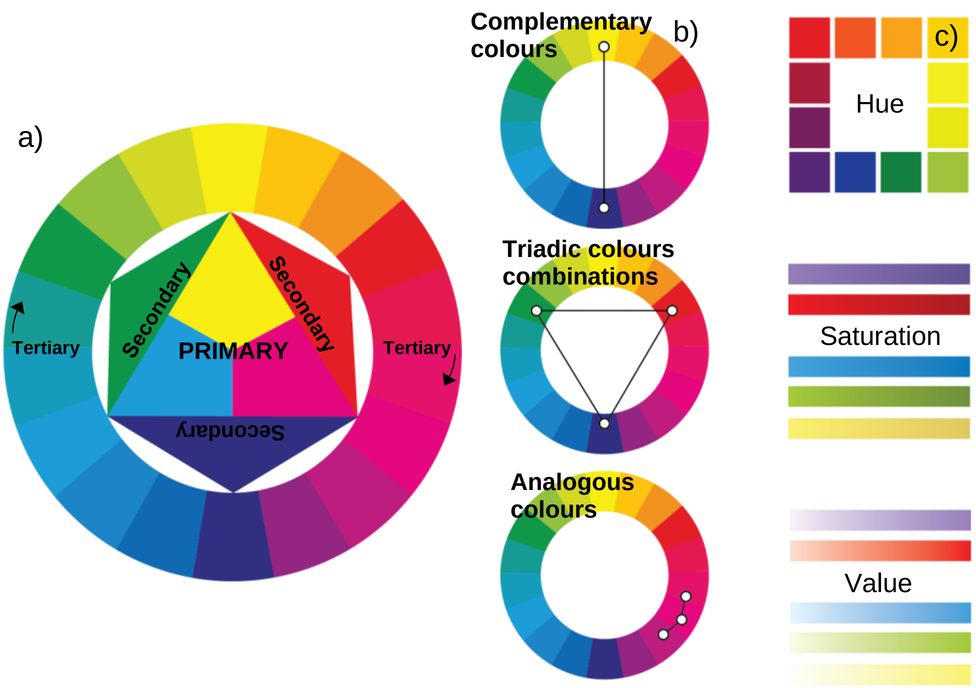


Figure 6: Physical characteristics of colour: a) colour wheel; b) colour harmony; c) colour properties. Adapted from: #EstudoEmCasa – República Portuguesa and Procriativo Agência Multimídia.

Beyond the physical characteristics of colour, colour theory also covers colour psychology. Colour psychology is the study of how colours affect perceptions, emotions, and behaviours. It is a crucial aspect of graphical design, allowing the creation of visual messages. Each individual, depending on their cultural background, interprets colour slightly differently. For example, black in western cultures is intrinsically linked with grief and death; although in China, this is associated with white. Also, in the 19th century, green was associated with poison due to the chemical arsenic. Nowadays, green is related to spring and ecology. Despite these differences, some colours have a universal meaning. For example, while red, orange and yellow are perceived as warm, healthy, and stimulating, blues and greens are seen as cold, calm, and sad (Heller, 2015; Inglis, 2023). Figure 7 exemplifies the meaning associated with determinate colours.

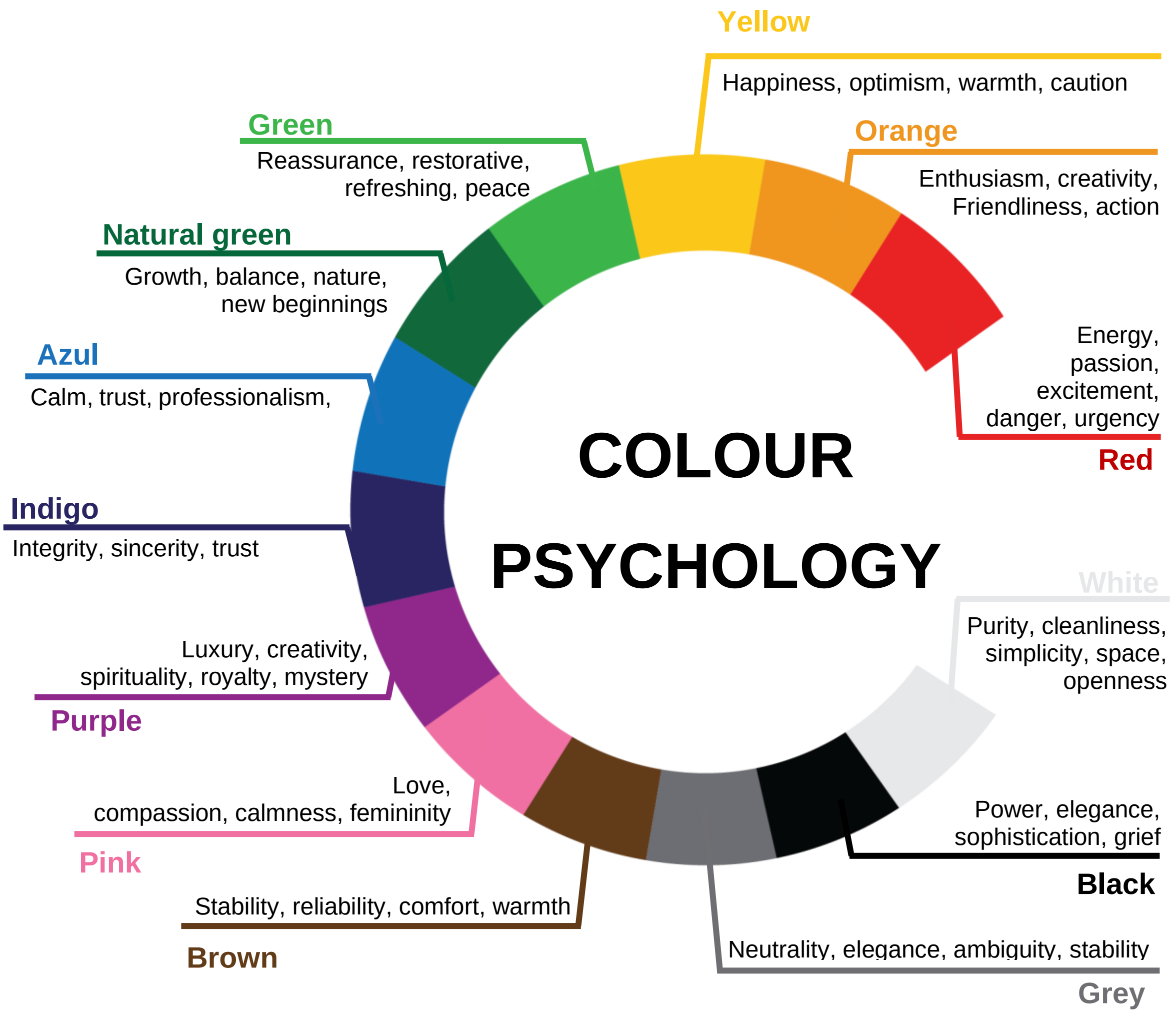


Figure 7: Colour psychology. Adapted from: Procriativo Agência Multimídia.

III. Grid and layout

Graphic design is the organisation of visual material (Inglis, 2023). Faced with this task, most people favour order over chaos and look to create a system to best present their given content within the required confines: grid. Grids serve two purposes: making the designer's role easier and more logical and making the information simpler for viewers' interpretation. A grid is a structural framework composed of vertical and horizontal lines, dividing a page into columns and rows, which serve as a guide for placing elements on a page, ensuring consistency and alignment of visual elements. Each grid system is composed of a set of alignment-based elements that function as guides for organizing and displaying visual aspects in a compositional layout. Layout refers to the arrangement and organization of visual elements, such as text, images, and other graphical elements of the design. Every design is different and therefore requires a grid system that meets its specific needs. However, there are some common elements to all grid systems forming the grid anatomy. Margins, columns, rows, modules, spatial zones, flowlines, markers, and gutters constitute the grid anatomy (Ambrose, 2007; Poulin, 2018a). Figure 8 explains this in more detail.

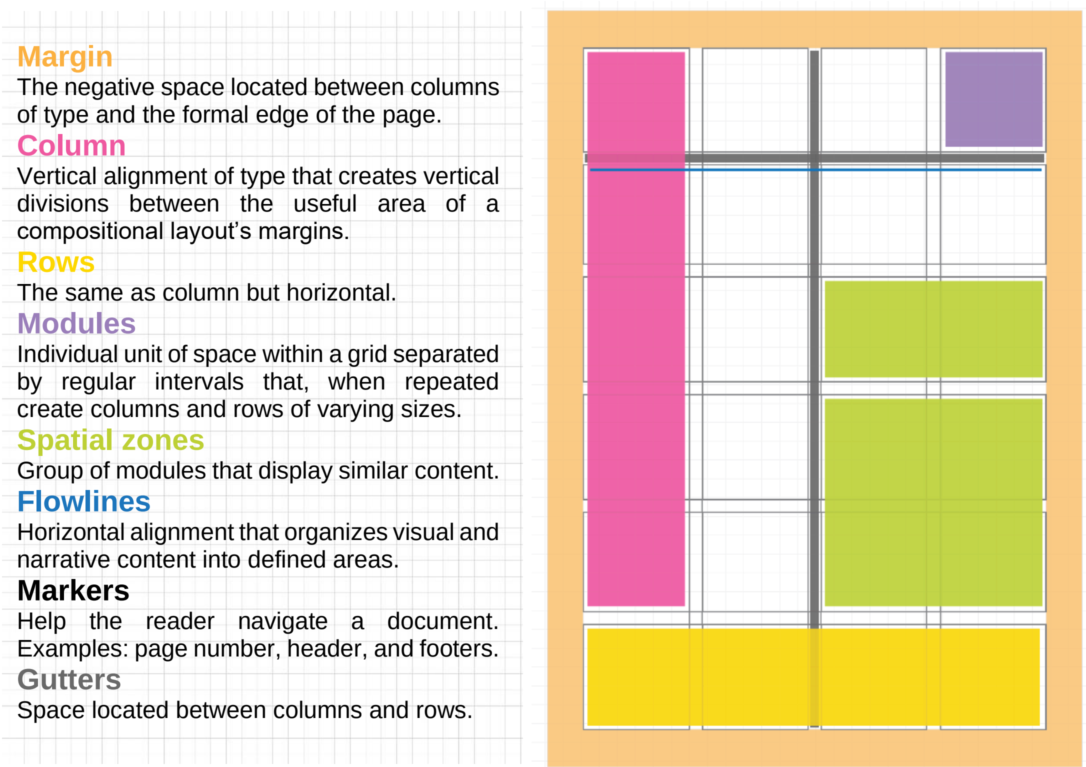


Figure 8: Grid anatomy. Adapted from: studypool.com

The elements of the grid anatomy can be arranged in diverse ways, consisting of various grid systems. There are six main grid systems, them being: the manuscript grid, the symmetrical and asymmetrical grid, the modular grid, the baseline grid, and the hierarchical grid (Ambrose, 2007; Poulin, 2018b).

- Manuscript grid (block grid): It is the simplest type. Derives from written manuscripts of the early 14th and 15th centuries. It is typically used for text-heavy designs such as books and articles. It consists of a single column that provides a clear, straightforward layout. Can be symmetrical or asymmetrical.
- Symmetrical grid: The left and right-hand pages (verso and recto) of the document, are mirror images of one another. The inner margins of both pages are the same width as the outer margins, providing a symmetrical, balanced, visual appearance to the page spread. The text area of each page can consist of a single, double, or multiple-column grid as long as it is the same on both pages.
- Modular grid: It is composed of multiple horizontal and vertical columns that form distinct spatial zones (usually squares). This is a multiple-column grid with a series of horizontal flowlines that subdivide the multiple vertical columns into multiple rows. It is often used in complex designs such as websites, where content needs to be arranged more intricately.
- Asymmetrical grid: The recto and verso pages are not symmetrical. Thus, an asymmetrical, or imbalanced, visual appearance to a page spread occurs. It can be columnar or modular.
- Baseline grid: It comprises a series of equally spaced, parallel baselines for the placement of continuous narrative text, large-scale type, and related visual elements. This grid is particularly useful for maintaining typographic consistency.
- Hierarchical grid: It is a composed system of alignments and zones for text and images that varies from page to page. The column width and proportion are directly derived from diverse visual and narrative content. It is used when the content requires a less rigid structure, providing a flexible framework that adapts to the design's needs.

Figure 9 shows examples of each one of the grid systems referred to above.

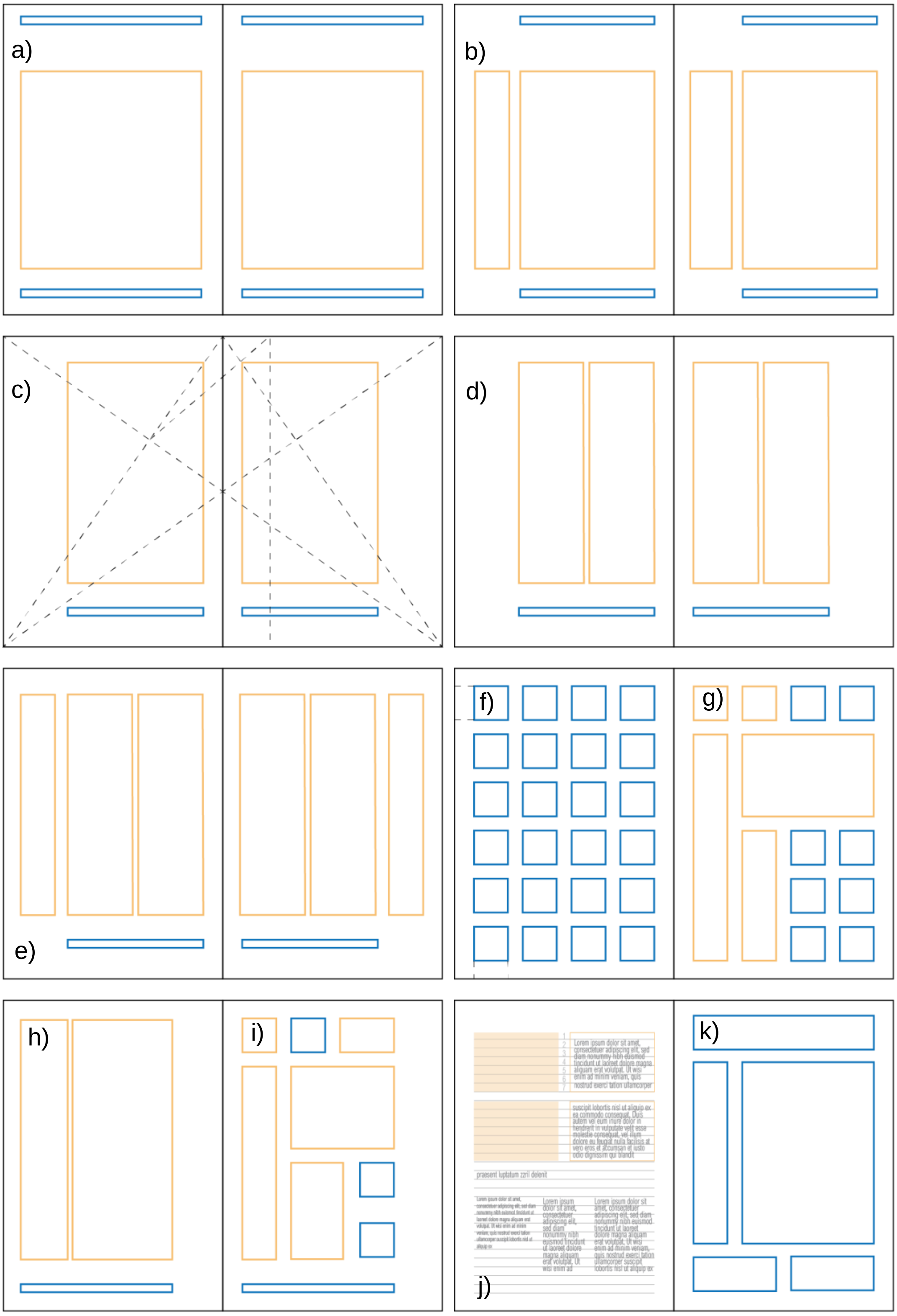


Figure 9: Grid systems. a) manuscript grid symmetrical; b) manuscript grid asymmetrical; c) symmetrical grid (single-column); d) symmetrical grid (double-column); e) symmetrical grid (multi-column); f) modular grid; g) modular grid with spatial zones; h) asymmetrical columnar grid; i) asymmetrical modular grid; j) baseline grid; k) hierarchical grid. Adapted from: Poulin, R., Grid Systems, in Design School Layout A Practical Guide For Students And Designers 2018, Rockport Publishers: Beverly, USA.

IV. Typography

Typography is a technique of arranging *type* to make written language legible, readable, and visually appealing. To better understand typography it is necessary to get familiarised with a complex set of terms (Inglis, 2023):

- Typeface: Refers to a design set of alphanumeric characters, which can be in different weights and styles while remaining consistent. For example, Helvetica is a typeface.
- Font: Refers to a specific style of a typeface. Helvetica is a typeface, while Helvetica Bold Italic is a font.
- Weight: Refers to the heaviness of the strokes in a font. Fonts with thinner strokes are usually labelled as light, with the thinnest known as extra-light. At the heavier end of the scale comes bold and extra-bold.
- Glyph: Glyphs are the individual characters of a font, whether that be a number, letter, or symbol. A font may have multiple glyphs of the same character.
- Swash: Is an ornamental addition to a glyph, i.e. an extension or embellishment of an existing part of a letter.
- Ligature: Two characters are connected and united into a single glyph.
- Case: Uppercase refers to capital letters, while lowercase refers to small letters.
- Italic: Refers to a type that is slanted forward, often used for emphasis or to differentiate between text.
- Kerning: Refers to the space between two letters.
- Tracking: Refers to the space between all the letters.
- Baseline: The line on which glyphs sit.
- X-height: Distance between the baseline and the top of a lowercase (not ascender). The letter x serves as an indicator.
- Ascender: Parts of a lowercase letter that extend above the x-height.
- Descender: Parts of a lowercase letter that drop below the baseline.
- Cap Height: Refers to the distance occupied by an uppercase letter.

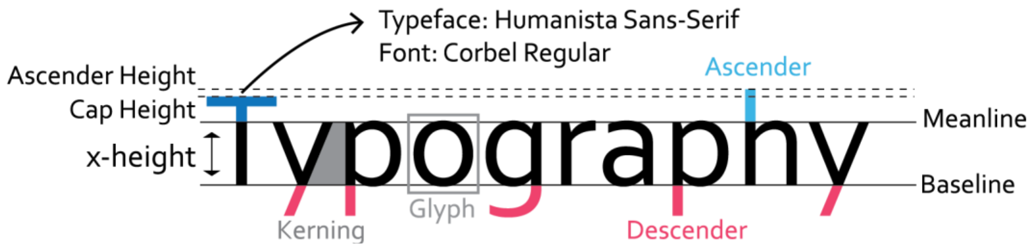


Figure 10: Terminology of type.

There are numerous different typefaces. However, many of them have similarities between each other. Thereby, classification systems were developed to group them into families. Nowadays, the most accepted system is the VOX-ATYPI Classification System. This system distinguishes thirteen families of type based on several formal criteria. The classifications are (Inglis, 2023; Tomisa et al., 2013):

- Humanist: Includes typefaces such as Centaur, Cloister and Jenson. Stands out by heavy and short bracketed serifs on descenders, and slanted *serifs* on ascenders. The lowercase ‘e’ features a diagonal cross stroke.
- Garalde: Includes typefaces such as Bembo, Garamond, and Sabon. It is characterized by a slanted axis. In contrast with the humanist family, it does not include serifs on ascenders and presents finer proportions.
- Transitional: Inspired by both old and classic type designs. Includes typefaces such as Baskerville, Perpetua, and Times New Roman. It is characterized by a vertical axis on the strokes and an inclined axis for curved strokes. Furthermore, this family presents bracketed serifs and slanted serifs on ascenders.
- Didone: Includes typefaces such as Bodoni, Didot, and Walbaum. The contrast between the thick and thin strokes is dramatic, looking different to every other that had come before. Besides the contrast between strokes, there is very little to no bracketing on serifs and terminals often have a “ball” shape”.
- Mechanistic: As the name suggests, this mechanical style presents a thick and rectangular serif. Includes typefaces such as Clarendon, Egyptienne, Ionic No.5 and Rockwell.
- Grotesque: Originating in the 19th century, this category contains early sans serifs. Includes typefaces such as Headline, Monotype 215, Monotype Grotesque, and Grot. No. 6. The main characteristics are that there is a slightly noticeable contrast between strokes, the lowercase ‘g’ is often “double story”, ‘R’ commonly has a curled leg, and the ‘G’ usually has a spur.
- Neo-grotesque: Contains many of the most famous sans serif typefaces, including Helvetica, Bell Gothic, DIN 1451 and Univers. Here the strokes present less variation in thickness, the lowercase ‘g’ is “single story”, and the uppercase ‘G’ does not present a spur.
- Geometric: It is characterized by an equal or almost equal stroke width. As the name suggests, glyph forms are influenced by geometric forms. This makes these typefaces less readable and harder to distinguish. Furthermore, they do not include serifs. Includes typefaces such as Avenir, ITC Bauhaus, Eurostile, Futura and Harmonia Sans.

- Glyphic: These are based on engravings of letterforms within materials such as stone or metal. Because of this, they have small triangular-shaped serifs or flared terminals. These typefaces often do not contain lower cases. Includes typefaces such as Albertus, Copperplate Gothic, and Trajan.
- Script: These appear to be written with a quill, thus often containing ligatures. Furthermore, these are characterized by a strong slope. Includes typefaces such as Francesca, Mistral, and Shelley.
- Graphic: By far the broadest typeface category. These are intended for display purposes only. Banco and Klang are examples of typefaces in this category.
- Blackletter: These are based on the medieval scribe handwritten with broad-nibbed pens. Includes typefaces such as Fracktur, Schwabacher, and Textur.
- Gaelic: These originated from Irish insular scripts found on medieval manuscripts. Nowadays is used for decorative purposes. Examples include Ceanannas, Corcaigh, and Doire.
- Non-latin: As the Vox type classification is very Latin-based, non-Latin types are very underrepresented. These include all non-latin typefaces regardless of style.

Figure 11 summarizes visually the main characteristics of each type category of the VOX-ATYPI classification system.

Figure 11: VOX-ATYPI classification system. Adapted from: lisagamerdesing.co.uk

2.2.6. Limitations

GAs are a valuable tool for summarizing and visually representing the key points of a scientific article. However, they have several disadvantages and limitations. Critics argue that GAs are not always effective in communicating the main findings of a study. Firstly, there is a risk of oversimplifying complex scientific data, potentially omitting key details of the research. Secondly, some studies may not be suitable for visual representation, rendering a GA unnecessary. These issues are due to the lack of universal standards for GAs. This reflects potential inconsistencies in their formats and contents. Additionally, the time investment and costs attached to the development of high-quality GAs comprise relevant limitations. The development of GAIs requires a good understanding of design principles and access to specialized software and tools (Lee & Yoo, 2023).

Despite these challenges, GAs have significant potential to overcome their limitations. Establishing standards for the use and creation of GAs is fundamental. These standards must be defined according to the target audience of the GAs, considering the distinct needs each one requires. GAs are increasingly used to engage and promote science (Ibrahim et al., 2017). However, while there are numerous studies that fundament the impact of GAs to increase journal impact and citation rates, fewer studies emphasize their role in engaging non-specialist audiences by boosting interest, comprehension and shareability. To extend the influence of GAs beyond the academic community, it is essential to design them with even greater accuracy and precision, considering that the academic audience is highly critical, and the general public may not scrutinize these visuals as closely. Therefore, investigating the impact of GAs on non-specialized audiences is essential. If significant benefits are observed, it could justify employing professionals to create GAs at research centres and publishers. This would ensure that GA are not only scientifically accurate but also correctly designed (Ibrahim, 2022; Lee & Yoo, 2023).

In conclusion, while GAs face certain limitations, their potential to enhance scientific communication and engagement is considerable. Establishing standards and further research into their impact on non-specialist audiences are necessary steps to fully realize their benefits.

Chapter 3: Methodology

3. Summary

In this chapter, we comprehensively describe the methodology adopted in the context of this investigation, establishing a solid foundation for the research findings and conclusions presented in the subsequent chapters. We cover key topics such as research design, survey design and development, and data collection and analysis. Additionally, the chapter presents potential limitations of the chosen methodology.

3.1. Research design

Different research frameworks shape how researchers plan and conduct their studies. These frameworks known as paradigms involve the underlying philosophical assumptions about its ontology, epistemology and methodology. Positivist, interpretive and critical are examples of paradigms. The paradigm selected impacts every aspect of a study, from the formulation of research questions to the analysis of results.

According to Clara Pereira Coutinho's classification paradigms, this investigation fits in the positivist paradigm. Also known as the empirical-analytical and rationalist paradigm, this paradigm seeks to adapt the investigation model of nature science to the social sciences field, to understand human behaviour (Coutinho, 2013). Here the hypothetico-deductive logical is employed, representing a circular model that initiates itself with a literature review, from which we formulate a testable hypothesis. To test this hypothesis, it is necessary to define manipulable (independent) and measurable (dependent) variables. These variables are the basis of the empirical study where the hypothesis will or not be acceptable based on experimentation. The obtained results are a valid complement to the existing literature, allowing the improvement of the knowledge on the topic in question (Park, 2020).

Figure 12: Deductive- hypothetical model.

There are unique characteristics that define the positivist paradigm:

- Ontology: Existence of a unique, objective and static reality that the researcher can observe and comprehend independently, using scientific methods to study it.
- Logic: Hypothetic-deductive model.
- Study goal: Describe, analyse, and explain social phenomena, by building and verifying theories.
- Data methodology: Preference to use quantitative methods for collecting and analysing data. Tendency to establish causal relationships between defined variables.
- Generalization: Identify consistent behaviour patterns that lead to theories and previews of future behaviour.

Some critics pointed out that the high complexity of social problems was highly diminished by the positivist approach, leading to the excessive simplicity of the social phenomenon, neglecting the diversity of perspectives and cultures of society. The objectivity and quantitative methodology might exclude important aspects such as individuals' experiences and values. These critics suggested a modified positivism paradigm: post-positivism. The latter recognizes the importance of considering cultural and personal contexts, considering inviable to achieve 100% objectivity in social studies. The paradigm allows the empirical and rigorous analysis of the scientific model and considers that there is no universal and static truth (Panhwar, 2017).

The present study fits into this paradigm, by following the hypothetico-deductive model, but at the same time ensuring the diversity within society. According to this paradigm, some individual perspectives are collected from the participants and integrated with the remaining quantitative data and analysis.

Descriptive methodologies are one of the most frequently used methods of investigation integrated into the (post-)positivism paradigm (Park, 2020) within the communication field. This approach has the objective of systematically describing a phenomenon or characteristic. It allows the analysis of behaviours, attitudes, values and situations, adding value to the pre-existing theoretical knowledge (Coutinho, 2013). In the present study, the adopted methodology fits into an inquiry research methodology, with a survey being the instrument of the investigation. This type of methodology is the collection of information from a population sample, through answers to the questions previously established by the researchers. Thus, the objective is to evaluate and describe the current state of the study object. The survey design employed here will be further discussed in the following sections but is important to note that the correlation studies also represent a relevant methodology in this investigation. Correlation studies have the objective to establish correlations between two or more variables in the same population or between the same variable in two distinct populations (Leedy, 2015). A correlation means that the "scores" of each variable are related in a non-random way (Almeida, 2017), i.e., a correlation exists when the increase of a variable, X, is reflected in an increase or decrease of a variable, Y, in a manner that occurs predictably (Leedy, 2015). The degree of correlation is determined by the coefficient of correlation that varies between 0, non-correlated, and 1, totally correlated (Coutinho, 2013). A correlation can be positive (X increases → Y increases), or negative (X increases → Y decreases) (Curtism E.; Comskey, 2015).

3.2. Survey design

Inquiries and polls have been used as a mean of obtaining information for decades. Historically these were used based on large samples on a population level and nowadays due to the evolvement of the methods and techniques applied to this type of analysis it is possible to consider smaller sample sizes, followed by generalization of the facts. For this to be possible, well-defined strategies had to be developed and adapted. It is imperative to establish clear objectives, methodologies, survey structure, and a representative sample of the population.

To achieve the objective established for this dissertation, we needed to understand a diverse range of factors involved with the use of GAs. Accordingly, an online survey methodology was implemented with the following objectives:

- Assess the impact of GAIs compared to TAs on Interest and Engagement
- Evaluate the comprehension of scientific information
- Understand the role of demographic factors
- Explore participants' behaviour and attitudes towards scientific articles
- Gather insights from scientific researchers

The author Clara Coutinho classifies three types of objectives in this type of investigation: descriptive, explanatory and exploratory. The first represents the classic inquiry, where the researcher tries to acknowledge the distribution of a variable on a representative sample of the considered population, with the ultimate goal of generalising the results. The second adds to the first objective by establishing relations between the studied variables. Finally, the exploratory study intends to extend the knowledge obtained to contribute to future studies (Coutinho, 2013). The present study has its main focus on the descriptive type of investigation. In terms of structure, survey research can be cross-sectional, as is the project here presented, or longitudinal. While the cross-sectional study collects data in a single moment, the longitudinal study collects data from the same subjects repeatedly over an extended period (Ponto, 2015).

3.2.1 Sampling

When investigating, the research group directs its study to a more or less specific section of the population, with certain common characteristics, to whom the researchers want to generalize the results. Most of the time the target audience of a study represents a large group – the population –, which makes it impossible to collect data from all of the population group. Considering the resources available, the researchers select a sample within the corresponding population. Therefore, a sample is a small group that the researchers select from the population through pre-defined sampling techniques (Coutinho, 2013). These techniques can be probabilistic or non-probabilistic. A probabilistic sample assures an equal probability of each individual belonging or not to the sample, and that this cannot be equal to zero. This type of sample is the one that moves further away from the occurrence of systematic error – bias –, however, it is the one that involves the greatest expenditure of resources. On the other hand, the non-probabilistic sample does not assure any probability of an individual belonging to the population (Taherdoost, 2016).

Our investigation presents a challenge regarding its target audience, consequently population and sample. We considered our target audience to be the general public older than 18 years, we want to understand the impact of GAs on non-specialized audiences but at the same time to understand the perspectives of some experts on this science communication tool. This means that our population has enormous dimensions, and there are not any exclusion criteria, other than the minimum age of 18 due to ethical and data protection policies and specific characteristics of the population under 18 that could compromise the study with factors not considered. Taking this into account, there were 2 options we could choose from: buy the service of an online platform that could provide us with a representative sample of this population, certain that it would imply cost and time to achieve it or collect a non-probabilistic sample and make it be the closest to representative of the population as possible. Due to available resources and the context of this dissertation, we opted for the last. Specifically, we choose to implement a particular case of convenience sampling. In the convenience sample, the participants are selected due to their accessibility and readiness to integrate the study (Hill, 2008). However, in our case, the participants are self-selected. The anonymous link of our online survey was made accessible to a broad audience (within the general public), through various channels like social networks, online platforms (institutional email and forums), and workplace distribution to maximize its reach. This approach has both advantages and disadvantages in its implementation that have to be considered. Firstly, by distributing the survey link widely, it maximizes its reach to a potentially diverse group of participants. Furthermore, this method is easy to implement and cost-effective since it leverages existing platforms and networks. On the other hand, the self-selection process might introduce some bias as well as the fact that there is not any assurance that the sample is representative of the population in question, limiting the generalization of the findings. We address these problems by implementing a wide range of distributing channels to ensure diversity, as well as by tracking the demographic characteristics of the respondents to identify any underrepresented groups.

3.3. Survey development

The development of the survey instrument is a critical aspect of this investigation, intended to ensure that the data collected accurately and effectively addresses the research objectives. The following section will describe the development of the online survey design for this study. This survey was developed on the *Qualtrics* platform due to its user-friendly interface, as well as a very wide range of options regarding the survey flow, a valuable characteristic due to the structure of our survey. The first step taken in the survey development was the GA design both at conceptual and design level. When these elements were finished, we structured the survey flow and questions to serve our objectives, integrating the GAs into it.

3.3.1. GA development

Concerning the GA development, the first step was to select the articles for which the GAs will be made. We decided to select three scientific articles to balance the depth and ease of the analysis. Three articles ensure that the study covers a diverse range of scientific topics and at the same time allows for a manageable amount of work within the time and resources available, without compromising the quality of the research outcomes.

Depending on its complexity level, certain specific scientific topics may not be effectively communicated to the general public. As has been described before, in science communication the essential goal is to transmit the scientific message emphasizing its relevance and impact to the considered audience. If the public cannot relate to the scientific topic, it will be challenging to raise awareness and interest ("The art of abstracts," 2011). Thus, the three scientific articles were selected based on their relevance to societal issues. Additionally, as the scientific background of the main part of the research team is biology, we focused on articles in that field to ensure scientific accuracy. Finally, we aimed to select articles where collaboration with the authors was feasible, ensuring we could obtain their authorization and feedback on the GA developed based on their work. Considering the strong relation of one of the elements in the research team with CIIMAR, we opted to select articles with correspondent authors of this institution. All things considered, the three scientific articles were: "Preliminary data on the occurrence of *Anisakis* spp. in European hake (*Merluccius merluccius*) caught off the Portuguese coast and on reports of human anisakiosis in Portugal" (Santos et al., 2022); "Are microplastics contributing to pollution-induced neurotoxicity? A pilot study with wild fish in real scenario" (Barboza, 2023); "Extensive gene loss parallels kidney aglomerulismo in Syngnathidae" (Pinto, 2023).

After finishing the first step, it was time to read all the articles and summarize the most relevant information to communicate to our audience. These texts served as the basis for the textual information present in the GAs. It was important to follow the information present on the TA, as the elements were to be compared posteriorly. In 2019, Randy Olson published a book where he described the ABT framework, a technique we implemented to summarize the relevant information in a small text. The ABT technique means "AND; BUT; THEREFORE" and defines a new tool to organize narratives and apply storytelling. This technique values contextualization (AND), the identification of a problem (BUT), and finally the presentation of a solution (THEREFORE) (Olson, 2019). For example:

AND	Communicators need to be able to tell stories **and** this is especially true for scientists.
BUT	**But** surprisingly, many of them are not trained to communicate with layman audience.
THEREFORE	**Therefore**, the ABT template can be used as a simple set of rules to help with

Figure 13: ABT framework.

After gathering all the conceptual information, the next step was to start the design process of the GAs. This process is similar for the three articles; thus, we will generalize it in the following description. Two versions of each GA were made, one in Portuguese and the other in English, to allow the participation of foreign individuals in the survey sample. The software used was the Adobe Illustrator 2024, version 28.5., and the dimensions of the artboards were defined as 20 cm width and 12 cm height. During the design process, the feedback and input of the article's authors and the research team led to diverse adjustments and improvements made to the GAs, either on clarity, scientific accuracy or visual appeal. Thus, the development of the GAs was a collaborative and iterative process aiming to effectively communicate scientific information to a non-expert audience.

All GAs started as a sketch on paper, where we defined the type of GA that suited best our needs and its layout. Considering our audience, objectives, and literature review, we opted for the GAI type. In terms of layout, we considered it was fundamental that the three GAs had similar aesthetics and elements. According to the literature, GAIs have to include the title, relevant logotypes, GA's author and the citation of the article that represents (Ibrahim, 2016; Rossi, 2017). At the same time, the context and problem in question should have a clear section, as well as the results and the conclusion. Additionally, as a GAI type, it is recommended to add a featured image to this element.

Figure 14 represents the general sketch of the GAs layout.

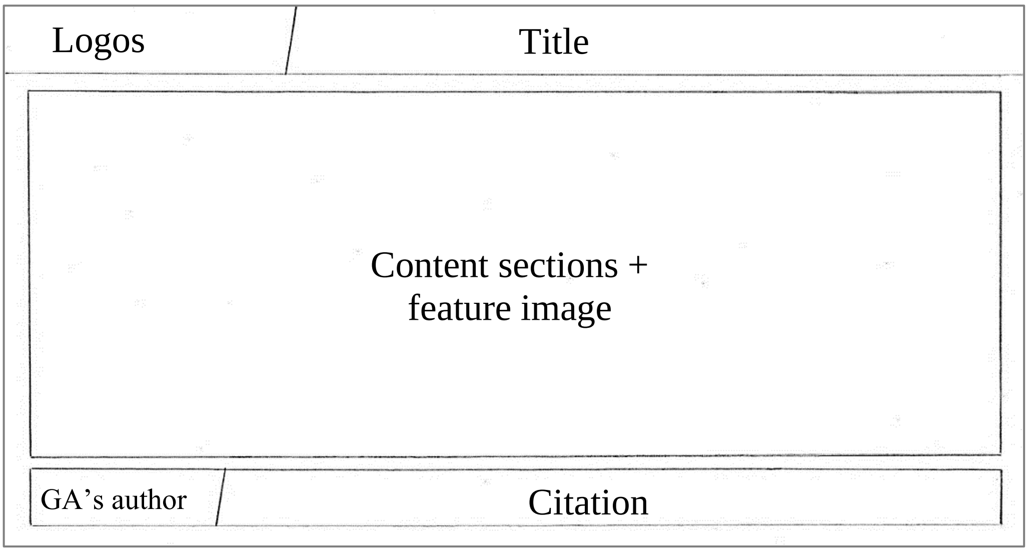


Figure 14: Layout sketch.

In the content sections, the context, key findings and conclusions of the article were displayed using visual cues such as icons, graphics and colour coding to draw attention. These designs were based on all the theoretical principles referred to in the literature review. The next section offers a detailed description of the development of each one of the GAs.

3.3.1.1 *Anisakis* GAI

The main goal is to effectively communicate the article's key points, thus the information needed to be accessible, engaging and easy to understand. The key points to communicate in the *Anisakis* GAI were:

- The prevalence of *Anisakis* larvae in European hake.
- Comparison of infection levels from two different analyses conducted in 2015 and 2021.
- Health risks associated with consuming infected fish.
- The need for better clinical data and regulatory measures.

Figure 15 shows the final result of the *Anisakis* GAI:

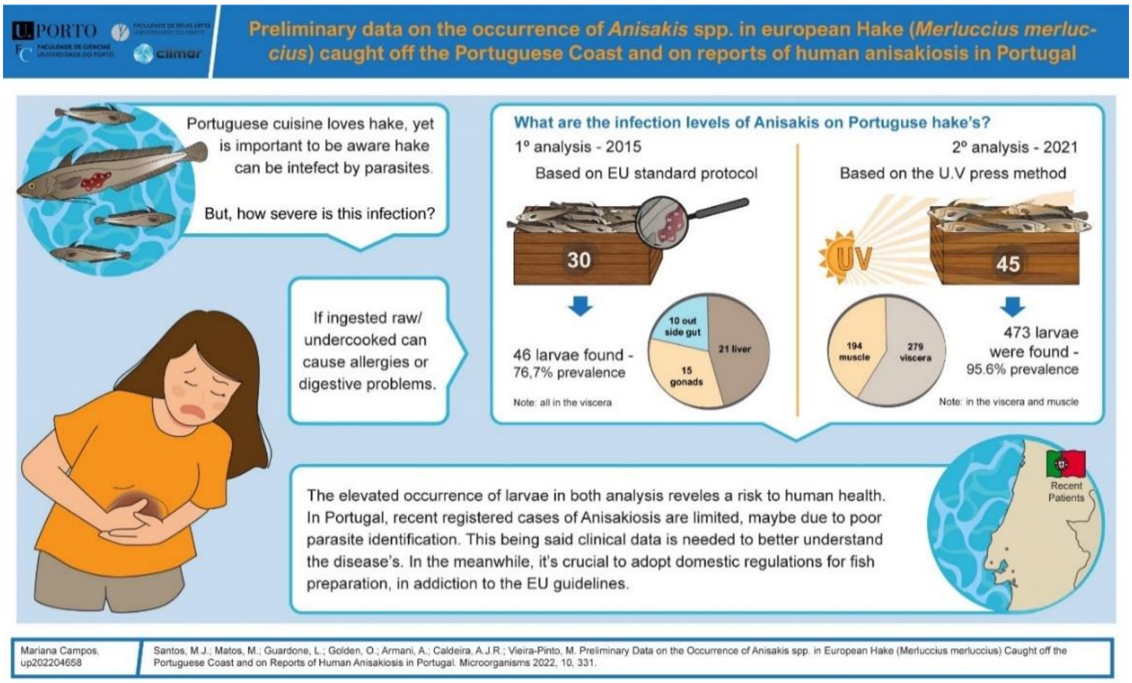
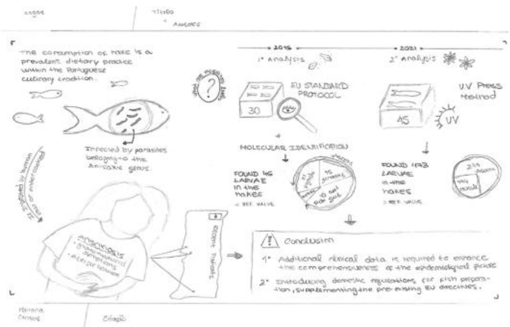


Figure 15: Graphical abstract - *anisakis* article.

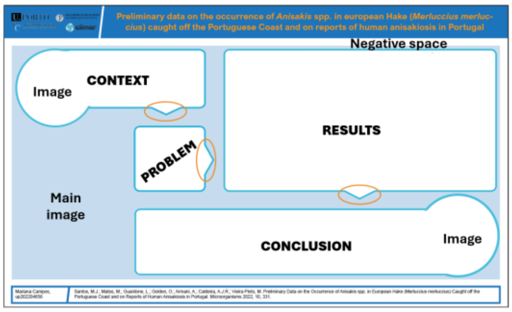
The textual elements were designed to be clear and consistent, ensuring comprehension by a non-expert audience. Text boxes were strategically used to segment the information establishing a logical and coherent flow. The layout started with the context, followed by the problem, study methods and results, and finally the conclusions. This compartmentalized structure, along with directional arrows in each text box, guides the reader effectively through the narrative.

The visual elements included clear and simple illustrations such as a person experiencing stomach pain to represent the health risks, adding a relatable human dimension. The illustrations adopted a cartoon-like style characterized by clean lines and simple shapes, avoiding unnecessary detail to highlight the key features that help transmit the main message without overwhelming the viewer (Inglis, 2023).

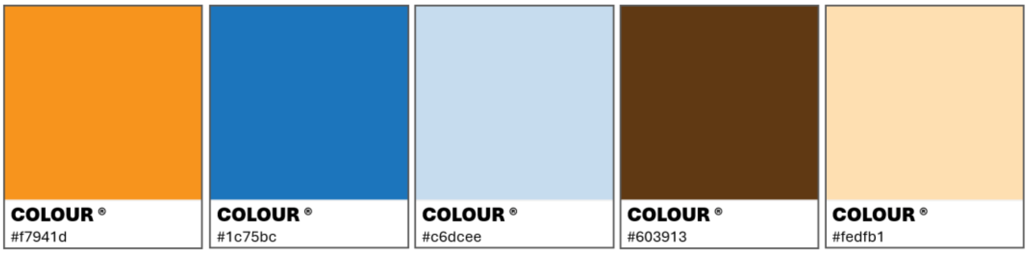
To facilitate the interpretation and comparison of results, circular graphics were employed. The primary colour used was blue, in various tones, to evoke the marine environment and resonate with elements such as the sea and the ocean. Orange was selected as an accent colour due to its level of contrast with blue and its psychological association with “taking action”. The sequence of figures below shows the relevant steps of the design process.



a) First sketch



b) Layout



c) Colour palette

d) Illustrations

Figure 16: Essential steps of Anisakis GAI development.

3.3.1.2 *Microplastic* GAI

The key points to communicate in the Microplastics GAI were:

- Fishes commonly consumed by humans ingest microplastics due to rising pollution levels.
- In the summer, microplastics were found in the brains of sea bass, correlated with low AChE activity.
- Reduced AChE activity affects fish quality and poses risks to food security and human health.
- Emphasizing the need to reduce plastic production, improve recycling and further research the impact of microplastics.

Figure 17 shows the final result of the Microplastics GAI:

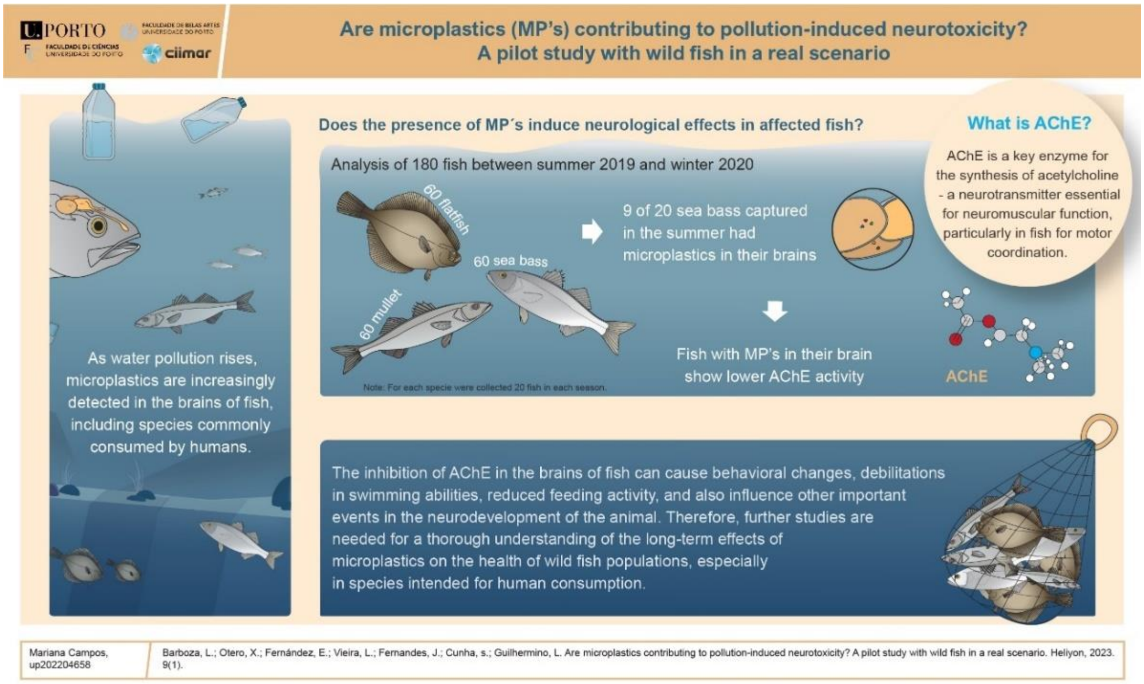
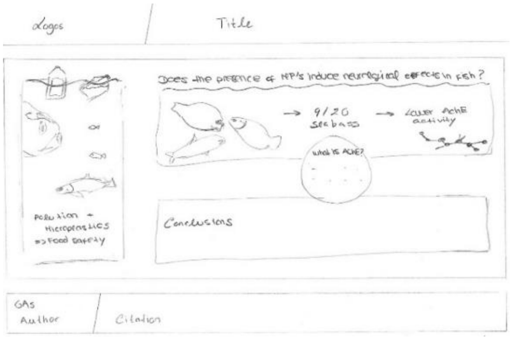


Figure 17: Graphical abstract - microplastics article.

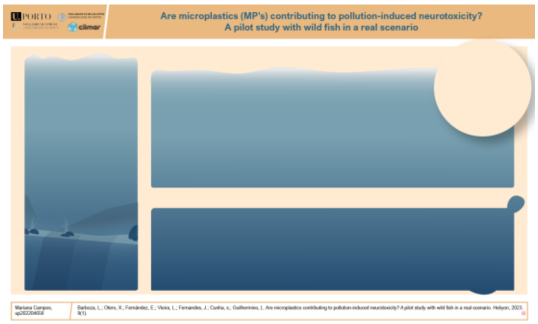
Taking advantage of the typical reading direction, from left to right and top to down, we divided the information into three blocks. We applied a gradient representing the ocean to maintain continuity between these information blocks, transitioning from its surface to its depths. The first block, containing the context information, features icons and visual elements relevant to this context, such as water bottles floating on the surface, rocks on the ocean floor, and a variety of fish. The background in this block was designed following the techniques of perspective drawing.

The fish illustrations were designed to balance the scientific accuracy with the cartoon-style illustrations typical of GAIs. An additional section was included to explain the technical term AChE. Recognizing the importance of this term, we added a clear and simple definition, along with a visual representation of the enzyme, even though this information was not present in the TA.

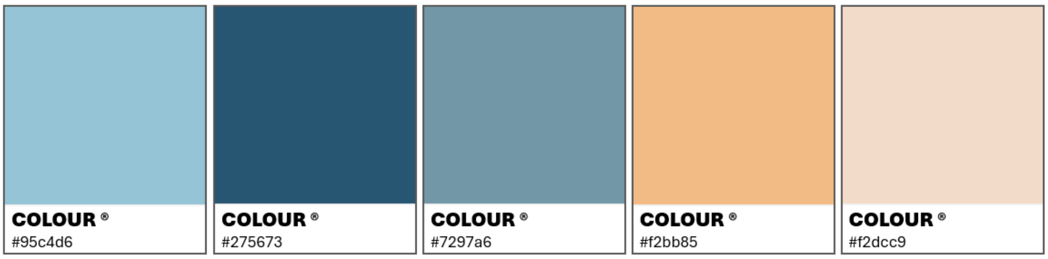
Regarding the colour palette, once more several shades of blue were chosen as the primary colour to reflect the marine environment of the scientific topic. The sequence of figures below shows the relevant steps of the design process.



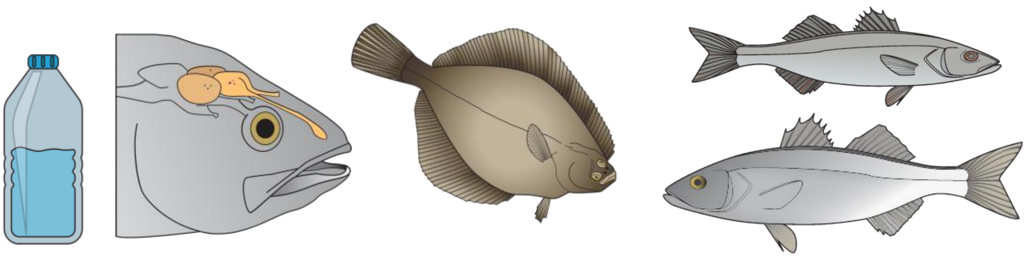
a) First sketch



b) Layout



c) Colour palette



d) Illustrations

Figure 18: Essential steps of microplastics GAI development.

3.3.1.2 *Seahorse* GAI

The key points to communicate in the Seahorse GAI were:

- The evolutionary adaptations of the seahorse's kidney anatomy due to its low-energy lifestyle.
- The genetic basis for the aglomerular kidney structure in Syngnathidae species.
- The deletions of the nphs1 and nphs2 genes and their role in kidney function.
- Insights into the evolutionary mechanisms and biodiversity.

Figure 18 shows the final result of the Seahorse GAI:

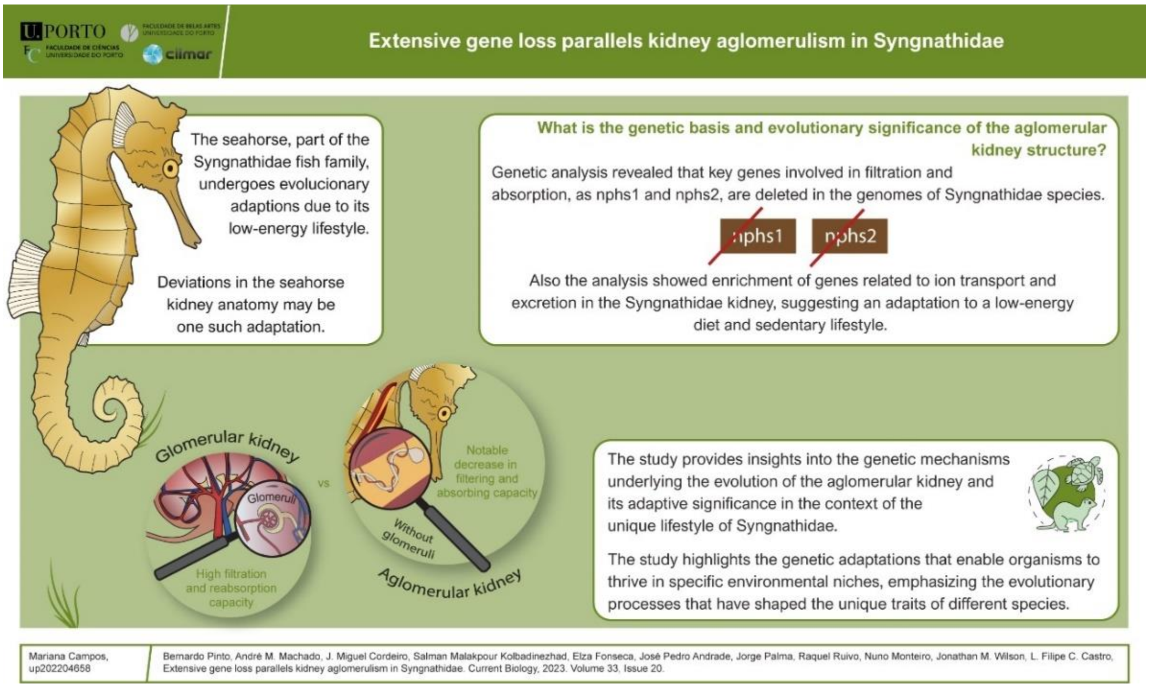
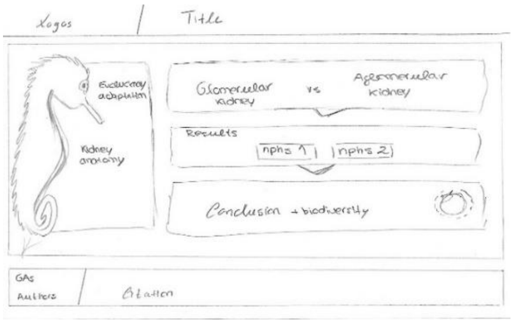


Figure 19: Graphical abstract - seahorse article.

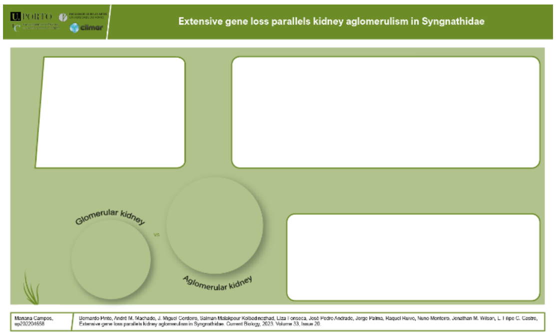
When we selected this article, we acknowledged that this topic was more complex than the other two, primarily because it did not have direct consequences for the considered audience. Nevertheless, we believed it was important to understand the potential impact of GAIs and considered this topic to be relevant enough to communicate to a non-expert audience. By increasing the complexity of the topic, we aimed to deepen the insights that the results could provide.

The seahorse illustration serves as the main visual element of the GAI, representing the central "character" of this article. This illustration was designed to balance scientific accuracy with the simplified illustrations typical of GAIs. Another key section of the GAI is the comparative illustrations of the kidney types. The general public recognizes the human glomerular kidney, so comparing it with the aglomerular type discussed in the article was the most effective way to engage the public and provide a visual reference for the new kidney type.

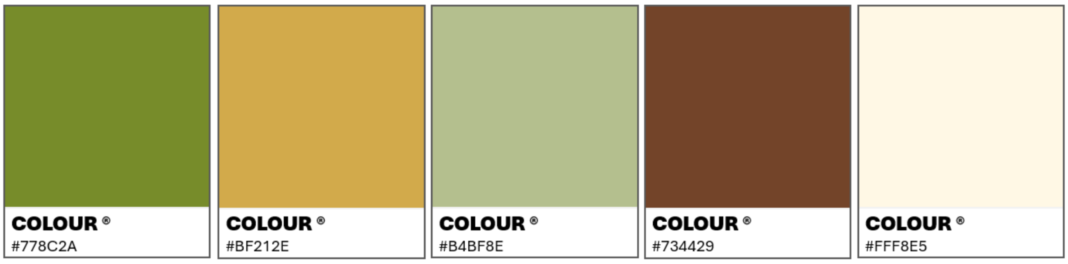
Regarding the genetic aspect, our objective with the schematic representation was to highlight the deletion of specific genes from the seahorse genome. For the colour palette, we chose green and earthy tones due to their psychological association with the natural environment. The sequence of figures below shows the relevant steps of the design process.



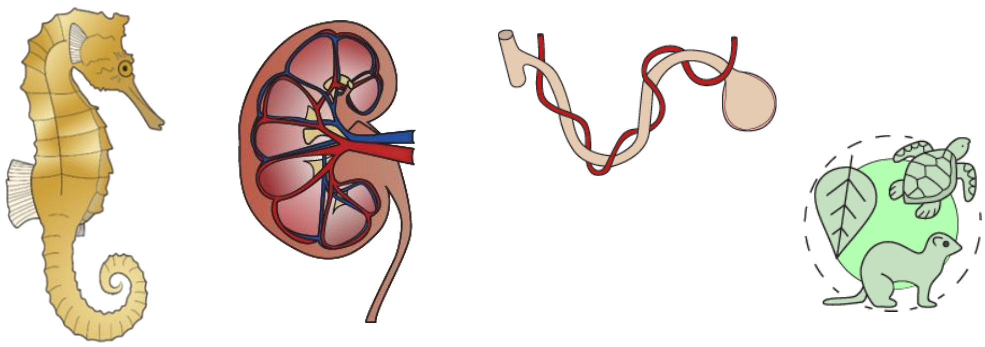
a) First sketch



b) Layout



c) Colour palette



d) Illustrations

Figure 20: Essential steps of seahorse GAI development.

3.3.2. Survey structure

The online survey developed for this dissertation was designed to capture a wide range of data related to the impact of GAs on a non-expert audience. This included the definition of a survey structure that effectively guides the participants through the survey progress and collects data according to the analysis intended in this context. It is important to note that the online survey developed had a Portuguese and an English version.

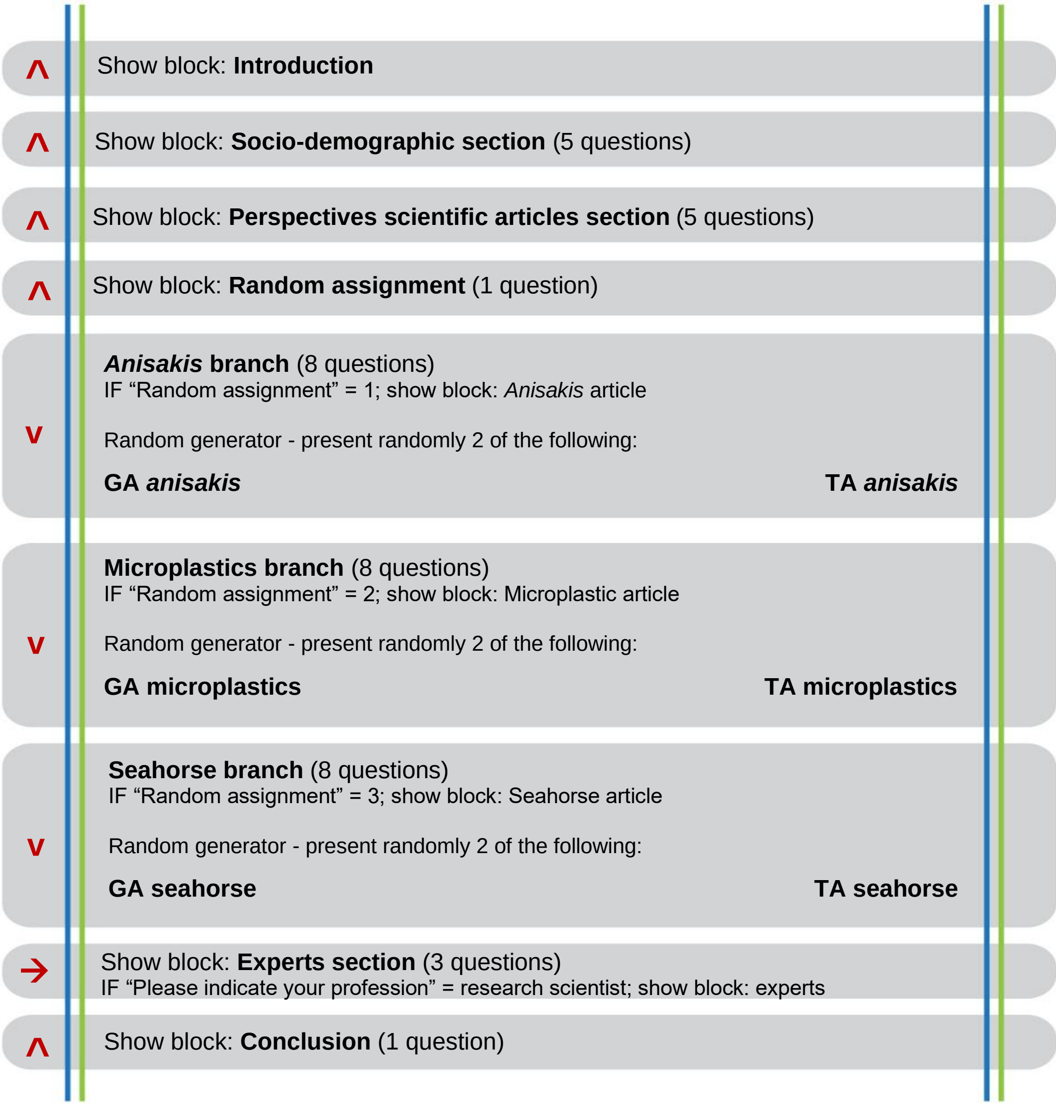


Figure 21: Survey flow (^ = and; v = or; → = if^).

The survey is structured into 7 sections. The first section is an introduction designed to inform participants about the purpose of the study, the nature of their participation, and the use of the data collected. The survey title was defined as "Types of abstracts in scientific articles and its disclosure to a non-expert audience", to ensure its neutrality and effectively transmitting the study focus. Apart from the pleasantly phrased welcoming tone of the introduction, it was important to reassure the participants that all the answers given would be used only for research purposes, guaranteeing strict anonymity and confidentially. Furthermore, the participants were informed that completing the survey implied their informed consent. Thus, this section served as a legal and ethical safeguard, ensuring participants were fully aware of their rights and the use of their data. Before data collection, ethical approval was obtained from the Ethical Commission of the Faculty of Sciences of the University of Porto, as evidenced by the approval document included in the Attachment [1] with reference Proc. CE2024/p151. Additionally, as a consequence of the distribution channels used, the survey was also approved on 11/04/2024 by the Unit of Data Protection of the University of Porto. Moreover, information such as the estimated time required to complete the survey, a brief explanation of GAs and the research team's contacts (in case of difficulties or doubts) were included in the introduction text.

The following sections of the survey consisted of several questions, related to a diverse range of topics, that allowed us to understand the position of the participants. Figure 21 demonstrates the survey flow. The socio-demographic section collected basic demographic information from the participants, including their age group, gender, nationality, and education level. This information was essential to understand the diversity of the survey sample and correlate these variables with others in the data analysis. The next section was designed to understand the point where our sample stands concerning scientific articles and science communication. Thus, this section aimed to understand the participants' baseline engagement with scientific literature. These general question section ended with a last question related to the article's attribution. Here the participants randomly chose a number between 1 and 3, and each number led to a main set of questions about a certain article's branch. Number 1 coded the *Anisakis* article; number 2 coded the Microplastics article; and number 3 coded the Seahorse article. The order in which the numerical option appeared is random. Summarizing each participant only answered about one of the three articles selected.

The article branches are the main sections of the survey and the ones that collected the most relevant data for our study. For the sake of simplicity, from now on, we will refer to GAI as GA. Each of these branches started with an introductory text explaining the topic of the assigned article and the structure of the branch. Each branch was divided into two subsections: GA and TA (see Attachment [2] for fully understanding of the structure). While the GA subsection (of all article's branches) included the respective GA, the TA subsection (of all article's branches) included a copy of the respective TA. Within each branch, both subsections consisted of the same 8 questions, and it was asked the participants to answer them about the GA and the TA separately. This allowed the posterior comparison of the results within each article. The order in which each section appears is random. Furthermore, across articles, each set of 8 questions is very similar, changing only on specific topic-related points. Once more, these similarities allowed us to subsequently compare results across articles and generalize the results to all the samples.

The socio-demographic section includes a question about the profession of the participant. This question was intended to filter the scientific researchers who participated in the questionnaire. Those who selected the option “scientific researcher”, were directed, after answering the main branch, to a section for experts only where their perspectives on the GAs were asked.

Finally, there was a last question to evaluate the perspectives of the participants on science communication. This was included in the survey to understand the coherence of the participants and the impact of this questionnaire on their opinion about science communication, since there was a previous question (in the perspectives scientific articles sections) where the fundamental information asked was similar.

In the following section, we will describe in detail the type of questions included in the survey and the rationality behind them.

3.3.3. Questions

The development of the survey questions is a critical step in the survey development process, as these questions are essential to ensure that the data collection is relevant, reliable and valid. When developing the survey questions, the primary consideration should be the overall objective of each question, especially, the type of information that the questions request. Survey questions can have several objectives such as obtaining facts, opinions, preferences, principles, attitudes and motivations. Once the objective is established, it is important to decide between general or specific questions, as well as between open-ended or close-ended questions. The distinction between general and specific questions lies in whether they inquire about a broad opinion/preference (objective) – general questions –, or about an opinion/preference (objective) regarding a particular case-specific question. For example:

General question example: <u>Do you like to work in groups?</u>

Specific question example: <u>Do you like to work in your current group?</u>

It is important to note that responses to these questions can differ significantly. A participant might generally enjoy working in groups but not appreciate the teammates of their current group. Therefore, is essential to carefully consider if the question reflects the intended information (Hill, 2008; público, 2021).

Regarding open-ended and close-ended questions, its difference lies in the way the answer is provided. Open-ended questions allow participants to write and structure their answers with their own words. In contrast, close-ended questions offer pre-determined answer options from which the participants can select one or more, depending on whether the question allows single or multiple choices. Both types have their advantages and disadvantages, making it essential to consider which type aligns better with the research objectives. Open-ended questions can yield richer and more detailed answers, often revealing unexpected insights. However, the analysis of these is more complex than the close-ended questions. It requires coding answers into categories and interpreting them, which often makes the application of advanced statistical methods challenging. On the other hand, close-ended questions provide simpler and more uniform data, facilitating the use of more complex statistical analysis. These formats, however, forfeit the depth and detail open-ended questions can provide (Hill, 2008; público, 2021).

Equally important in developing survey questions, is ensuring the clarity, neutrality and appropriate extension of the questions. Clarity is oppositely correlated with the extension of the question, and similarly, the use of technical terms can negatively impact understandability. As there is no precise tool to measure understandability, and the latter depends on who is supposed to understand, it is essential to consider the target audience when drafting the questions. Adapting the language and complexity of the questions to match the respondent's needs, enhances the probability of obtaining accurate and meaningful responses. Furthermore, when asking about opinions, attitudes, or satisfaction is necessary to ensure that the question is neutral. Questions with these objectives typically represent bipolar variables, so their format should not in any form appeal in favour of each pole, for example, negative or positive (Hill, 2008).

Focusing on the present study, the survey predominantly consisted of specific questions, as they relate to the particular case of each one of the selected scientific articles, and close-ended questions. However, there are three open-ended questions throughout the survey, namely:

- “Describe the word that best describes your first impression of the figure” – the first question of each GA subsection.
- “Describe the word that best describes your first impression of the figure” – the first question of each TA subsection.
- “If you want to share, indicate the disadvantages you find concerning the insertion of GAs in scientific articles” – the last question of the expert’s section.

These were incorporated into the survey to achieve deeper insights into participants' perspectives on the topic. The first two questions, although open-ended, had an established limited number of characters, making their analysis and interpretation simpler. The final question was included to understand the standing point of the researchers towards GA. This question aimed to complement and contextualize where the researchers stand about the GA, thus deciding to give them a space to do so freely. With this question, we aimed to complement and contextualize the quantitative data obtained from other survey variables, offering a more global view.

In addition to the 3 exceptionally open-ended questions, it is relevant to note the existence of two multiple-selection questions. In the perspectives on the scientific article section, participants could answer the question "Indicate why you read scientific articles" selecting more than one of the options provided. We opted to allow multiple answers because it would be restricting to consider that participants just have one motive to read scientific articles. The other multiple-selection question is the final one: "As a final consideration, select from the following list three options you consider to be the three main consequences of science communication". This question was intended for two different objectives. Firstly, we wanted to understand if in general, the participants considered the consequences of science communication to be mainly positive, mainly negative or both. Secondly, we wanted to check if the opinion of the participants remains generally the same (positive or negative) throughout the survey. This was possible because the second section of the survey had a question asking about the participant's opinion on the importance of science communication to a non-expert audience. Attachment [2] contains a copy of the complete survey where it is possible to access all questions made.

3.3.4. Answer options

While open-ended questions do not require further work after the definition of the question, close-ended questions require the definition of a group of alternative options – the possible answers. Each option is associated with a numerical code, which facilitates subsequent data analysis. Collectively, these numerical codes (options) represent measurement scales. Measurement scales typically are of two types: nominal scales or ordinal scales (Hill, 2008).

Nominal scales consist of a group of categorical answers, qualitatively different and mutually exclusive. Answers such as yes/no, and male/female/non-binary are examples of nominal scales. It is still possible to attribute a number to each category for analysis purposes, but the number does not represent a quantity difference between them; just identify each option. The same is not true for ordinal scales (Hill, 2008).

Ordinal scales employ a numerical ordination of their alternative options, meaning that there is an order relation between them. However, the magnitude of that difference is immeasurable. Due to the extra work involved in building a completely new scale, it is very common to use pre-validated rating scales to structure the alternative options. The Likert scale, introduced by Rensis Likert in 1932, is one of the most widely used psychometric tools in educational and social sciences research for measuring attitudes, perceptions, and opinions. The scale is designed to quantify qualitative attributes of human behaviour, thereby transforming subjective judgements into objective and quantitative data that can be analysed according to natural science statistical methods. In its final form, the Likert scale is an x-point scale that allows the participants to indicate their negative-to-positive strength of agreement or strength of feeling regarding the question. It can be applied to quantity, frequency, rating, satisfaction, probability, and agreement (Hill, 2008). Table 2 shows different settings of a Likert scale.

Table 2: Examples of Likert Scales

	1	2	3	4	5
FREQUENCY	Never	Rarely	Occasionally	Frequently	Very frequently
RATING	Very bad	Bad	Reasonable	Good	Very good
SATISFACTION	Very dissatisfied	Dissatisfied	Neither dissatisfied nor satisfied	Satisfied	Very satisfied
PROBABILITY	Impossible	Unlikely	Likely	Very likely	Certain
AGREEMENT	Totally disagree	Disagree	Neither agree nor disagree	Agree	Totally agree
IMPORTANCE	Not important	Slightly important	Moderately important	Important	Very important

Typically, Likert scales have 5 or 7 points, however, sometimes they might have 4 or 6 (respectively). The problem here is to decide between an odd or even set of alternative answers. Faced with an odd number of options, many participants might tend to a neutral and conservative answer (middle option). On the other hand, an even number of alternative options forces the participants to stand on one of the poles, making it impossible to give a neutral answer. There is no rule when it comes to this problem, although 4 point scales are commonly applied when the topic is more sensible and the participants might be more reductant in taking sides (Hill, 2008; Pal, 2015).

All things considered, we opted to apply ordinal scales, particularly Likert scales of 5 points, in the majority of the answer options present in the developed survey. The socio-demographic section is the exception, containing mainly nominal scale answer options. We decided to include 5-point scales in the alternative answers because the survey implemented here was anonymous and did not cover any sensitive topics. Additionally, in each article branch, there was a set of two questions to which we had to build a specific group of alternative questions, due to the nature of the question. These alternative options do not represent a continuous variable; thus, they are nominal scales. We intended to evaluate comprehension of each of the articles. Thus, the questions had to be multiple-choice questions (1 selection) with a single correct answer. One of the questions asked what the objective of the study was, and the other question asked the main finding of the study. To define the alternative options of these questions we began by identifying the correct objective and main finding of each of the articles and defined them as the correct alternative option. Then, we developed three alternative answers to each question that are plausible but incorrect, ensuring the clarity, consistency and relevance between the options. In Attachment [2] it is possible to access all the alternative options (answers options) in the survey.

3.3.5. Validity and reliability

All investigation projects look to ensure the veracity of their research tools, data and conclusions. Validity and reliability ensure the replicability of the data and the accuracy of the results, guaranteeing the integrity and quality of the research tools and the research itself (Mohajan, 2017).

Validity is defined as the degree to which a test or measuring instrument tests/measures what it is supposed to. Only if the instrument is valid, will we be able to make the interpretations we intend. There is a diverse range of validity types, although, in the social sciences field, there are three that stand out (Eaton, 2017):

- Content validity: represents the degree to which an instrument covers the range of meanings, related to the research topic.
- Construct validity: classic definition of validity – the degree to which a test or measuring instrument tests/measures the purpose for which it was designed.

- Criterion validity: represents the correlations of the measuring instrument with another already considered valid.

The validity of the present survey was assured by the review of the research team, as well as by a review done by Profª Clara Vasconcelos, Associate Professor at the Faculty of Sciences of the University of Porto with vast experience and specialization in research methodologies. Additionally, a pre-test was conducted with a small group of participants. The purpose of this pre-test was to identify and rectify any potential issues with the survey questions and answer options, such as ambiguity, complexity, clarity, and relevance. Five participants were chosen based on their availability and willingness to participate in the pre-test, and they were not related to the research topic and research objectives, which helped simulate the perspective of the target non-expert audience. The participants completed the survey independently and were asked to note any questions they found confusing or difficult to answer, as well as to provide general feedback on the survey length, structure and overall flow. Finally, based on the overall feedback, revisions were made to the survey, including rephrasing and structure adjustments.

On the other hand, reliability is defined as the degree to which a test or measuring instrument consistently tests/measures what it is supposed to. It is important to note that a reliable instrument does not imply a valid one because it is possible to obtain consistent results over time, with every result being associated with a certain error. In turn, the opposite is true in the majority of cases. Reliability is expressed in one of three formats (Coutinho, 2013):

- Equivalent forms reliability: two versions of the instrument applied at the same time.
- Test-retest reliability: the same instrument applied two times over time.
- Internal reliability (split-half): the instrument is applied once, and subsequently the data group is divided in two, and correlations are performed between the two sets of data.

Regarding reliability, we opted to estimate the internal reliability through Cronbach's alpha statistic. The maximum value taken by this statistic is 1, and the closer to 1, the better the reliability of the instrument. Due to the survey structure, it was necessary to perform this analysis in each article section separately. As the attribution of the article in the survey was random, this reflected in different *N* between each article's answers. The number of missing values when considering all the variables together led to an error in this analysis, thus we conducted the analysis section by section. The α value was 0,822 for the *Anisakis* section, 0,809 for the Microplastics section and 0,797 for the seahorse section. Considering the guide scale of interpreting Cronbach's alpha results, all the values stay in or close to the good reliability values (0.8 to 0.9) (Hill, 2008).

3.4. Data Analysis

The previous sections cover all the steps taken before the distribution of the survey. Once they were completed, the survey was distributed and opened for two months (3/04/2024 to 25/05/2024). After this period, we closed the survey and started the data analysis. The following sections outline the theoretical framework and methodologies employed to analyse the data.

Quantitative data analysis involves the application of several statistical techniques. These statistics can be descriptive or inductive. Descriptive statistics, such as mean, median, mode, frequency and standard deviation, describe the basic features of a database. On the other hand, inductive statistics involve the use of data from a sample to make inferences or generalizations about a population. This type of statistics applies to hypothesis testing research, definition of population parameters research and prediction research. Apart from this, statistics techniques can be classified as (Hill, 2008):

- Parametric and non-parametric techniques.
- Techniques that evaluate differences between samples.
- Techniques that evaluate relations between variables.

3.4.1. Parametric and non-parametric techniques

Parametric techniques work with the characteristics (parameters) of a certain Universe. These statistics make strong assumptions such as: the values of a variable have a normal distribution within the Universe in question, and the definition of the variable values as interval or ratio scales. Some examples are t-test, analysis of variance, Pearson Correlation and linear regression (Hill, 2008).

In contrast, non-parametric techniques do not assume a normal distribution of the variable values. Thus, these statistics allow us to analyse variables defined as ordinal or nominal scales. Examples are the Chi-square test, Wilcoxon test, McNemar test, Spearman correlation and test between medians (Hill, 2008; Siegel, 2014).

Considering the ordinal and nominal nature of the variables included in this study survey, all the tests employed in the data analysis consist of non-parametric techniques. From this point on, we will focus only on non-parametric techniques, considering the nature of our data.

3.4.2. Differences between samples (non-parametric)

As the name suggests the tests presented in this subsection are applied to compare two or more samples, for which the distributions do not follow the normal one. There are several tests designed to evaluate the difference between two or more samples, although depending on the nature of the relation between samples, there are tests more or less appropriate. The samples can be independent or dependent. While independent samples are measurements made on two different sets of items, dependent samples are paired measurements for one set of items. Table 3 presents non-parametric statistic techniques (Hill, 2008; Siegel, 2014).

Table 3: Non-parametric statistic techniques. Adapted from: Hill, M.M.H., A., Investigação por questionário 2008, Lisboa: Edições Sílabo.

Scale	Two independents samples	K independents samples	Two dependents samples	K dependents samples
ORDINAL	The median test The Mann-Whitney test **The Kolmogorov-Smirnov two sample test** Th e Wald-Wolfowitz run test The Moses test of extreme reactions	Extension of the median test **The Kruskal-Wallis one-way analysis of variance**	The sign test **The Wilcoxon matched-pairs signed-ranks test**	The Friedman two-way analysis of variance
NOMINAL	The chi-square test[1] The fisher's exact test (small sample size)[1]	Extension of the chi-square test	The McNemar test	The Cochran's Q test

1 - Test designed to assess the independence between variables in a contingency table.

3.4.3. Correlation between variables (non-parametric)

A coefficient is a descriptive statistic that explains the nature of the relation between the values of two variables. Typically, coefficients vary between [-1;1].

Regarding non-parametric techniques, the correlation coefficients can be association coefficients or correlation coefficients. The first measures the relation between two nominal variables and the last measures the relation between two ordinal variables (Hill, 2008).

Within the association coefficients, the most commonly used are (Hill, 2008):

- phi coefficient (φ): applies when both of the variables have only two values. Crossing type – 2 x 2.
- Cramér's V coefficient (φ_c): applies when one (or both) variables have more than two values. Crossing type – *r* x *k* (rows = r; columns = k).
- Contingency coefficient (C): applies to any type of crossing. However, its maximum is always lower than 1, and this value is dependent on the number of variable's values.

Within the correlation coefficients, the most commonly used are (Hill, 2008):

- Spearman's coefficient (ρ): measures the strength and direction of association between two ranked variables.
- Kendall rank coefficient ($\tau - b$): measures the strength and direction of association between at least one ordinal scale.
- Gamma coefficient (Y): measures the strength and direction of association between two ranked variables when these variables happen to have a lot of tied observations.

In the present study, the software chosen to analyse the data was IBM SPSS Statistics version 29.0.0.0. The first step was to transfer the data from the Qualtrics platform to SPSS, and then organize it, check labels, values and scales of each variable and do the necessary alterations to ensure every variable is correctly defined. Initially, the sample size (*N*) was 304 participants. However, when we started organizing the data, we realized that a considerable number of participants did not achieve 100% of the survey progress. In fact, 72 participants did not make it to the main section of the article (articles branch), the reason why their participation was disregarded. From the participants who reached the main section of the survey (232), we considered the participation of only those who completed at least 1 of the subsections of the main branch, i.e., completed the GA or TA subsection of the assigned article. After this selection, our *N* equalled 214, including 19 incomplete answers. We considered two incomplete answers from participants assigned to the *Anisakis* article, eleven of the participants assigned to the microplastics article, and six of the participants assigned to the seahorse article. Altogether, there were 48 participants assigned to the *Anisakis* article, 79 to the microplastic article and 87 to the seahorse article. Before distributing the survey, the research team defined sixty (60) as the minimum number of participants for the study to be viable. This value was determined based on pre-defined values, which state that to apply descriptive statistics the minimum *N* is 30; and to establish correlations between two groups, variables or samples, the minimum *N* is 60 (público, 2021). Based on this sample, we first analyse the frequencies of all the variables to understand a general distribution of the data. Regarding the open-ended questions, in which the data provided was qualitative, we opted to define certain categories that could accordingly represent the data and, at the same time, allow us to do a more comprehensive analysis of those results. For example, as has been described, the first question of each article's branch subsection was open-ended, and by categorizing those results, we were able to perform a cross table with a chi-square test applied, between the GA and TA results of each article. Subsequently, we performed Wilcoxon matched-pairs signed-ranks tests to compare the GA and TA variables within the same article. With the Wilcoxon test, we were able to understand if there was a significant difference between the variables analysed and determine that difference. Thus, based on the mean value of each variable, we determine a value of that difference (%), which indicates the direction of the difference. These were made by comparing the mean of a GA variable with the mean of the equivalent TA variable (remember that the questions, thus the variables, between GA and TA subsections were equal), and calculating the difference between them. Additionally, we performed several correlation analyses (applying correlation coefficient) which will be explained in more detail together with the results. Throughout the analysis, the p-value considered significant was smaller than 0.05 ($p\text{-value} < 0.05$), as it is typically adopted as the significance margin in the literature (Hill, 2008). It is important to note that the data resulting from the expert section was dealt with as complementary. Thus, only descriptive analyses were made regarding this data set.

Chapter 4: Results and Discussion

4. Summary

The following chapter presents the results obtained from this study, along with their interpretation and significance in the context of science communication. The chapter is divided into four main sections, namely: sample characterization, comparative analyses of GAs and TAs, expert analysis, and correlations. To ensure data coherence, due to different sample sizes, between articles, the results of each article are addressed separately.

4.1. Sample characterization

4.1.1. Socio demo-graphic parameters

This section provides a detailed overview of the socio-demographic characteristics of the study participants. The collection of socio-demographic data is essential to provide context for interpreting the findings and ensuring that the results apply to diverse segments of the population (Hill, 2008). Data such as gender, age group, nationality, education level and profession were collected.

I. Gender

Collecting data related to gender allowed us to examine potential differences in how males, females and non-binary individuals perceive and interact with the subject of study. From the total sample of 214 participants, 81 identify as male, 130 identify as female and 3 identify as non-binary. The sample has a higher proportion of female participants, 60.7% of the total sample. While having 37.9% of the participants identifying as male still provides a substantial number of male perspectives, the minimal representation of the non-binary category may limit the ability to draw significant conclusions about this category's perspectives. Chart 1 illustrates the distribution of the results.

II. Age group

Investigating how different age groups engage with GAs and TAs might help us identify if their format is effective across different age groups. This is important to evaluate because age typically impacts familiarity with digital media, visual literacy, and preferences for information presentation (Anderson, 2018), topics extensively covered in our analysis. The majority of our sample consisted of individuals with ages between 18 and 24 years old (*N* = 65). The age group with the second largest representation was the 25 to 34 years old (*N* = 51); followed by those aged between 45-54 years old (*N* = 38). The most underrepresented group was participants older than 65 years old (*N* = 7). Chart 2 represents the distribution of the results.

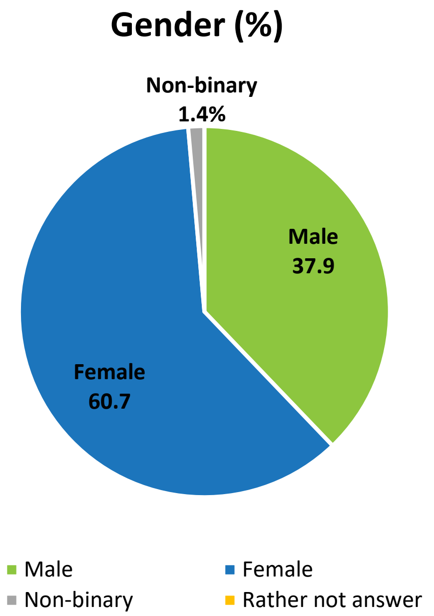


Chart 2: Frequency of gender results.

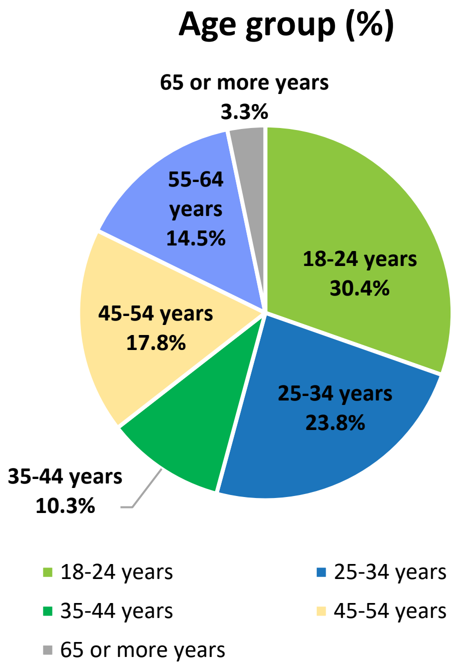


Chart 1: Frequency of age group results.

III. Nationality

Table 4: Frequency of nationalities results.

	Frequency *(N)*	Frequency (%)
Angolan	1	0.5
Brasilian	8	3.7
Cape Verdean	1	0.5
France	1	0.5
Indian	1	0.5
Pakistan	1	0.5
Poland	1	0.5
Portuguese	195	91.1
Romanian	1	0.5
Spanish	2	0.9
Turkish	2	0.9

The sample consists of participants from various nationalities. However, the vast majority of the participants are Portuguese (91.2%). This strong representation suggests that the findings of this study may be strongly influenced by the cultural, social and educational context in Portugal. Table 4 presents the distribution of the results.

IV. Qualifications

The education level often correlates with prior knowledge and experience with scientific content (Bartling, 2014). By collecting the qualifications of the sample, we aim to understand if the background and experience of each participant impact their engagement with the study object. Most participants hold a BSc degree (44.4%). The number of participants with an MSc degree (28.5) is relatively similar to those with a high school level of education (20.6). Both the lowest level of education, basic school level (*N* = 1), and the highest level of education, PhD degree (*N* = 13), are less represented. Chart 3 represents the distribution of the results.

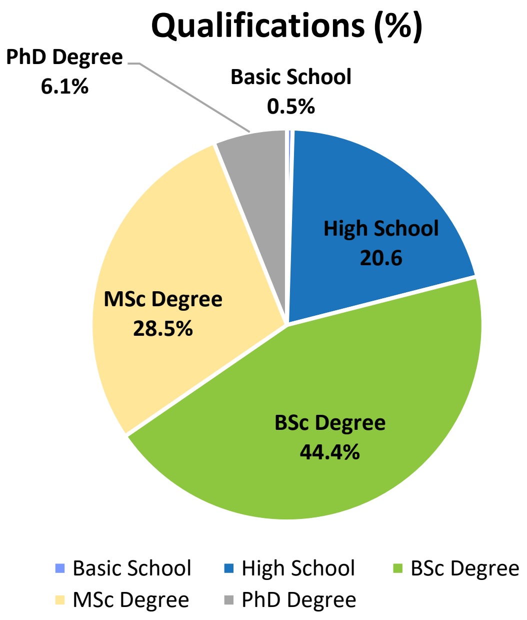


Chart 3: Frequency of qualifications results.

V. Profession

Regarding the profession data, we filtered the total sample to identify scientific researchers to direct them to the experts section of the survey. The data collected also complemented the information on participants' educational levels. From the total sample of 214 participants, 23 were scientific investigators (10.7%), 80 were students (37.4%) and the other 111 (51.9%) had a diverse range of jobs. Participants could specify their job roles if desired, 67 out of 111 participants did so. The most common professions included doctors, managers, nurses, teachers, and engineers. Table 5 represents the distribution of the results.

Table 5: Description of profession results.

	Frequency (*N*)	Frequency (%)
Student	80 + 2^1 = 82	38.3%
Scientific Investigator	23	10.7%
Other	111 - 2^1 = 109	50.9%

*67 of the 109 answered with their profession

N_{PT} = 109 (100%)[2]	Job (other)[4]	N_T = 214 (100%)[3]
N = 13 (11.92 %)	Nurse.	*N* = 13 (6.07 %)
N = 6 (5.51 %)	Manager.	*N* = 6 (2.80 %)
N = 5 (4.59 %)	Doctor; teacher.	*N* = 5 (2.34 %)
N = 3 (2.75 %)	Engineer; consultant.	*N* = 3 (1.40 %)
N = 2 (1.83 %)	Software developers.	*N* = 2 (0.94 %)
N = 1 (0.92%)	Academic text review; clean room technician; event manager; HR manager; IT; Karate instructor; Management assistant; Manager and inspector of the tax and customs authority; Oral hygienist; Personal trainer; Pharmacy technician; Physiotherapist; Quality assurance; Retired from baking; retired from public administration; sales assistant; senior services consultant; software developer, software engineer, technical assistant.	*N* = 1 (0.47 %)

1 – Two participants who selected others and included their job role description wrote PhD students. Despite special statute of a PhD, we decided to consider them in the student category.

2 - The percentage frequency presented refers to the partial total sample of *N* = 119. 10 of the participants did not clearly describe their job roles; thus, their answer was disregarded. These represent 9.17% of the partial total (*N* = 119), and 4.67% of the total samples (*N* = 214).

3 – The percentage frequency presented refers to the total sample of *N* = 214.

4 – Each job in this column was written the number of times present in the corresponding line, i.e. “nurse” occurred 13 times.

4.1.2. Scientific articles parameters

This section provides a detailed overview of how the participants engage with scientific articles and their perspectives on science communication before the intervention of the survey. The collection of this data provides background information, allowing us to understand participants' prior interactions with scientific articles and their views on science communication before the survey was implemented.

I. Reading frequency

The frequency of reading scientific articles may influence how participants perceive and interact with the elements under study. The results indicate that a similar portion of the sample reads articles frequently (*N* = 73) and occasionally (*N* = 65). Likewise, a comparable number of participants read articles very frequently (*N* = 39) and rarely (*N* = 31). A small number of participants reported never reading scientific articles (N = 6). Chart 4 represents the overall distribution of this data.

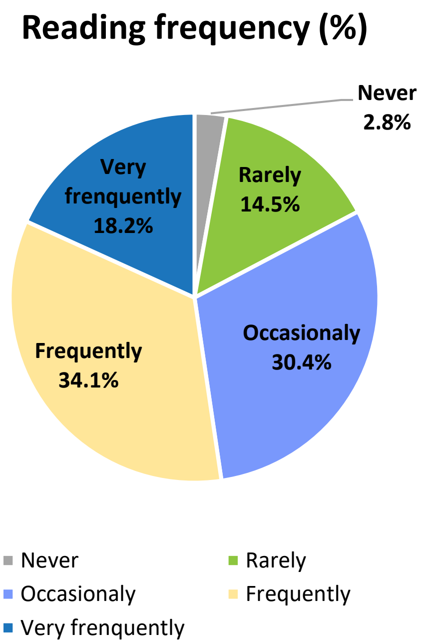


Chart 4: Frequency of reading frequency results.

II. Motives to read

Understanding the reasons why the participants read scientific articles provides valuable information about their motivations and the contexts in which they engage with scientific literature. This information may help identify how specific scientific communication tools, like those studied here, meet the needs and interests of different audiences. Since six participants answered "never" to the reading frequency question, they did not answer this question (N_{PT} = 208). Data shows that the most common motive for reading scientific articles is academic purpose (selected 122 times). Considering that the sample is constituted of 82 students and 23 researchers, together representing approximately 50% of the sample, it was expected that academic motives would be the most frequent among the participants. However, the selection of the other two provided options, professional and personal, was similarly high, being chosen 106 and 107 times, respectively. Two participants indicated their own reasons under the "other" option. When analysing the combination of motives selected by the participants, "only academic" motives remain the most frequent choice, followed by "only professional" motives. Despite this tendency, together, the number of participants who selected more than one option only ended up being slightly higher (N = 111) than the number of participants who selected a single option (N = 103). This diversity in motives highlights the multifaceted nature of public interaction with science. Chart 5 shows the distribution of results.

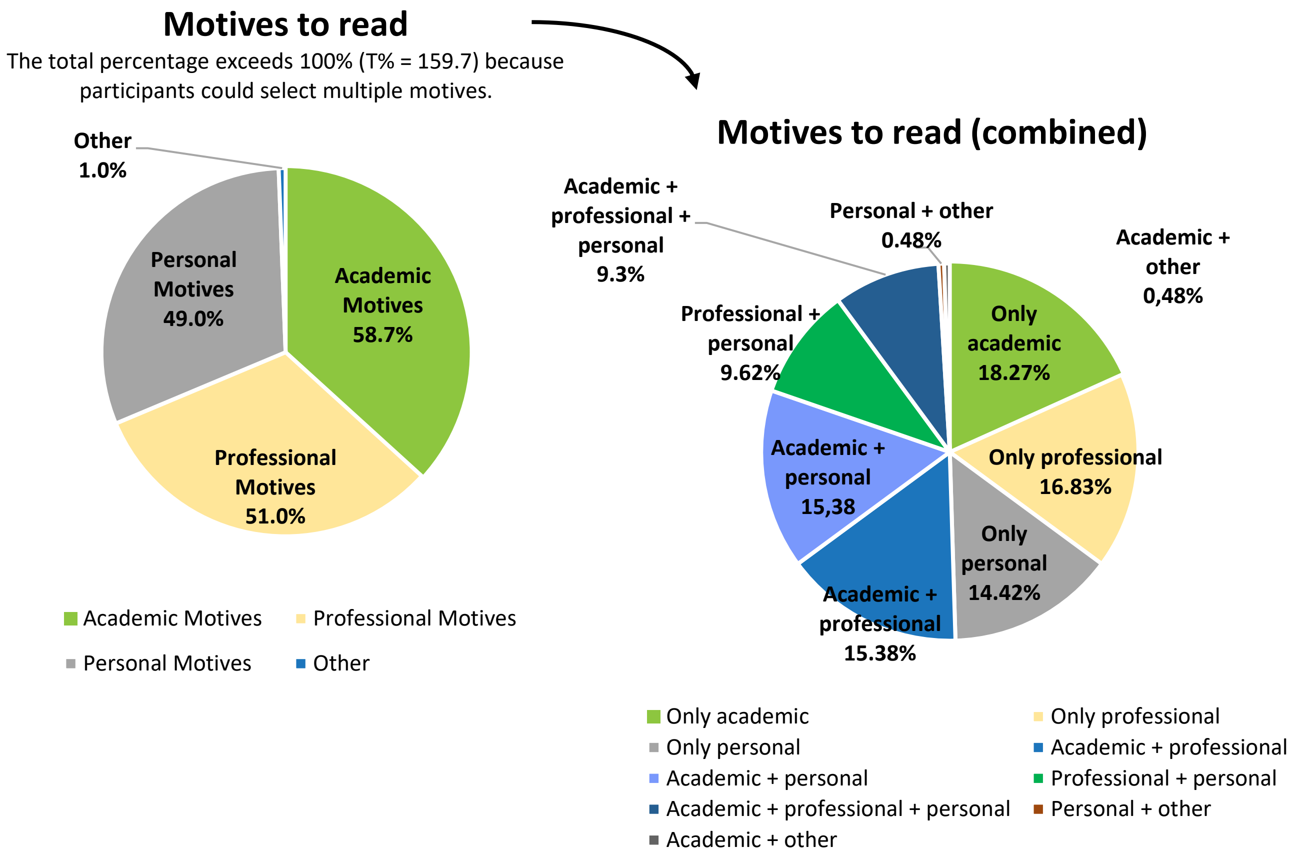


Chart 5: Motives to read scientific articles.

III. Expert-only articles

Assessing participants' views of accessibility concerning scientific articles might help identify potential barriers (public predisposition) within science communication. In this case, the majority of the sample (N = 149), nearly 70%, either totally or partially disagreed that scientific articles should only be directed to experts. On the other pole, approximately 22% of the participants (*N* = 46) partially or totally agreed with the statement. Understanding how this latter group interacted with the GA and TA will provide valuable insights into the impact of these scientific communication tools on engaging audiences not predisposed to science. Chart 6 illustrates the distribution of results.

IV. Importance of science communication

We aimed to determine the importance participants attribute to communicating science to the general public. All the participants considered science communication to be important, being strongly convinced that science communication is “very important” (N = 130). Chart 7 represents the distribution of the results.

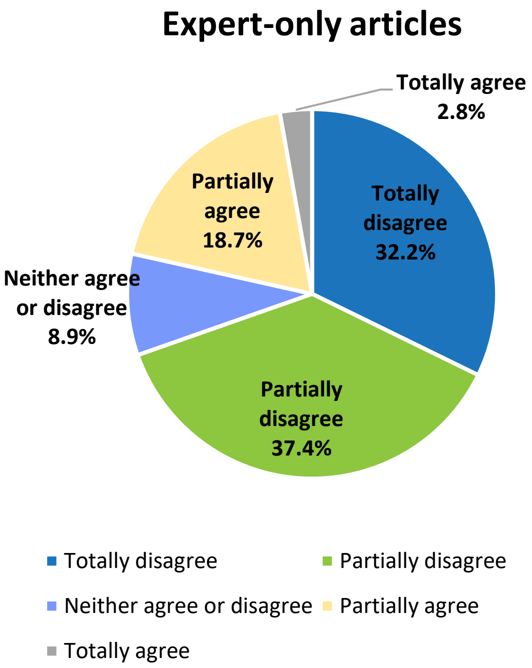


Chart 7: Frequency of expert-only articles results.

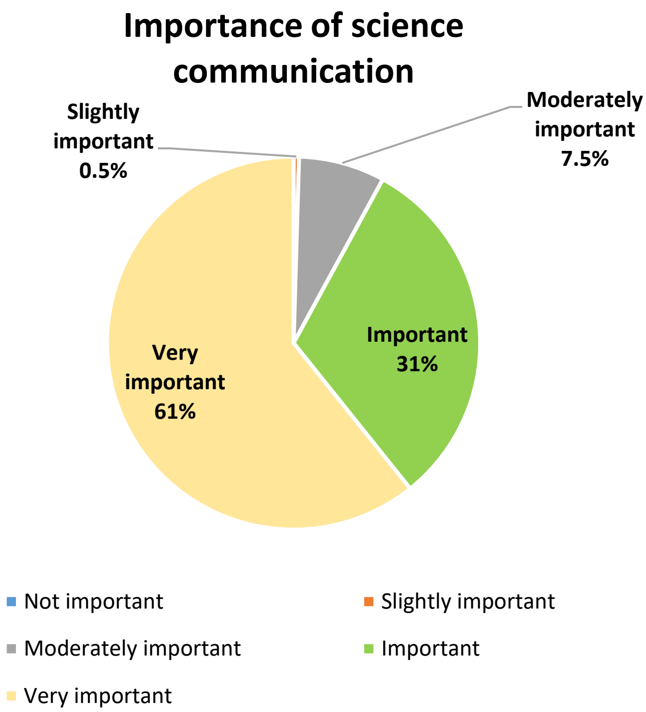


Chart 6: Frequency of science communication results.

The final question of the survey was designed to assess the initial and final opinion of the participants about science communication. The intention was to compare the results of the above question with this final one, being the first the initial position of the participants about science communication and the final one the final position of the participants towards this subject (after the intervention of the instrument). More than 90% of the participants already considered science communication important or very important in the first question. In the last question, due to its multiple answers nature, the participants could select their options from the 10 provided. The options provided included positive and negative consequences of science communication. As Table 6 illustrates, more than 95% of the participants selected positive options on the consequences of science communication. This reveals that the participants maintained their positive perspective on science communication, thus the survey did not in any way compromise the opinion of the participants about science communication.

Table 6: Descriptive results of final question.

	N (times selected)	Frequency (%)
Public access	124	63.9
Public involvement	97	50
Informed decisions	111	57.2
Innovation	61	31.4
Demystification	64	33.0
Conscientization	88	45.4
Sensationalism	9	4.6
Politicization	6	3.1
Distrust	8	4.1
Devaluation	5	2.6

4.2. Comparison between GAs and TAs

The purpose of this section is to present and discuss the comparative analysis between GAs and TAs across several key variables. The main objective of this study is to determine if there are significant differences between GAs and TAs across several key variables. Ultimately, we aim to evaluate the impact and effectiveness of GAs in comparison to TAs. Due to the varying numbers of participants assigned to each of the three selected scientific articles, the results were analysed individually for each article. This section is divided into four subsections: *Anisakis* article, microplastics article, seahorse article, and overall discussion. In the first three subsections, the results for each key variable are presented in pairs, comparing GAs and TAs. Each article's subsections begin with an analysis of the frequency of each variable, followed by an assessment of normality and tests for differences between variables. If a significant difference is found, the mean is used to calculate the value of that difference. At the end, a general discussion about all articles together is provided.

4.2.1. *Anisakis* article

Forty-eight participants were assigned to the *Anisakis* article. Out of these, two were incomplete answers. One participant answered only the GA subsection, while the other participant completed both subsections but did not answer the final question. In this context, we intended to compare GA and TA results on variables such as first impression; interest in the topic; comprehension; importance to a wider field; interest in knowing more; agreement to read the complete article; and likelihood of interaction in social networks.

I. First impression

The first question of each subsection asked the first impression of the participant either on the GA or the TA element. This was an open-ended question, thus before analysing it, it was necessary to categorize the answers to be able to compare them. This categorization was made based on the objective of the question and the answers given, ending up with 5 categories: positive, negative, neutral, feelings on the topic, and scientific related. Attachment [3] shows the detailed categorization based on all the answers given. Chart 8 represents the frequency of each category in the GA and TA subsections.

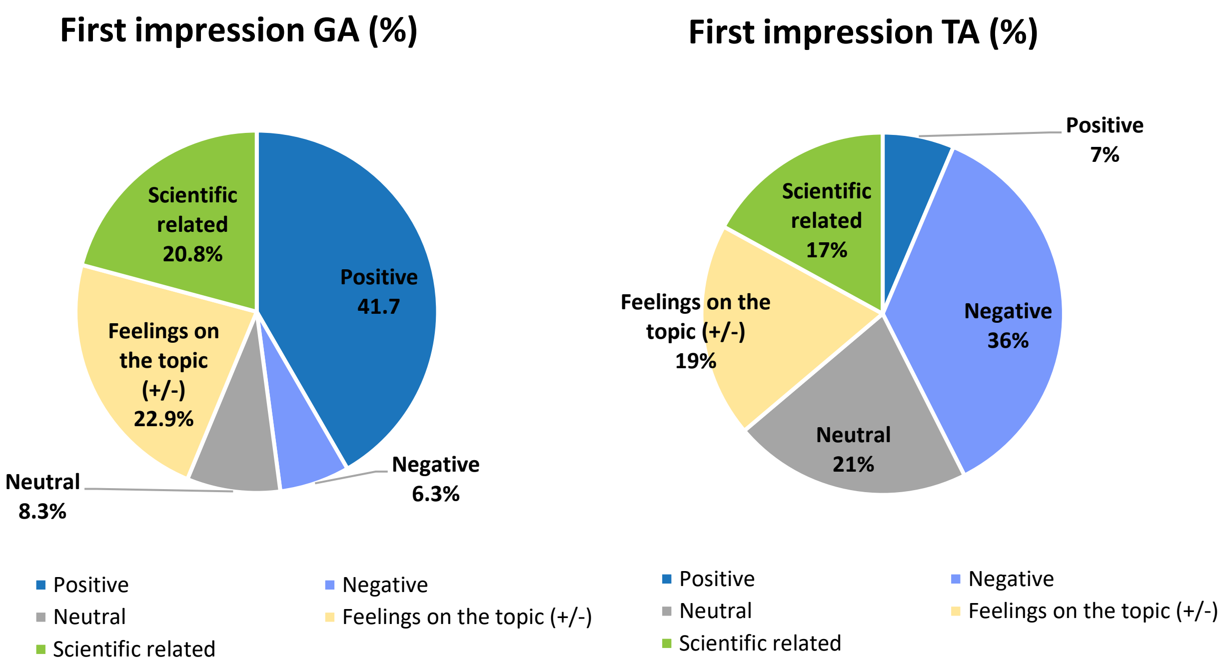


Chart 8: Frequency of 1st impression categories GA and TA – *anisakis*.

It is clear that when compared to TAs, GAs received a significantly higher proportion of positive first impressions, namely 41.7% of the participants assigned to the *Anisakis* article. Oppositely, the TA received a higher proportion of negative first impressions (36%) compared to the GA (6.3%). As for the remaining categories, the participants had more neutral impressions of the TA, revealing a higher capacity of the GA to make the participants take a stronger position, suggesting a stronger emotional or cognitive engagement, a positive aspect in science communication perspectives (Fischhoff, 2013).

Table 7: Crosstable GA and TA (1st impression) – *anisakis*.

Chi-square test

Pearson's chi square: 31.359

Degrees of freedom: 16

p-value = 0.012

Categories GA (1st imp.) \ Categories TA (1st imp.)	P(+)	N(-)	N(0)	FT	SR	NTTA
P(+)	1	8	5	4	2	20
N(-)	0	1	1	1	0	3
N(0)	1	1	2	0	0	4
FT	1	6	0	4	0	11
SR	0	1	2	0	6	9
NTGA	3	17	10	9	8	47

Categories: P(+) – positive; N(-) – Negative; N(0) – Neutral; FT – Feelings on the topic; SR – Scientific Related.

Table 7 shows the distribution of first impression categories for the GA in comparison to the TA, representing in each cell, the specific first impression for both the GA and the TA. Additionally, a chi-square test was performed to assess the association between both variables. This test allows us to assess if these differences are statistically significant. The p-value obtained (0.012) indicates a statistically significant association between the type of abstract and the first impression categories, suggesting that the type of abstract influences how participants perceive the content at first glance. Therefore, the differences found between both variables, are not due to random chance, implying a real impact depending on the type of abstract. These results could show that GAs engage readers quickly and more effectively than TAs, potentially making them more effective in communicating scientific information to a broader audience (J.E. Thomas, 2006).

II. Engagement and interaction

Table 9: Frequency of engagement and interaction variables GA section - anisakis.

		1	2	3	4	5	
Interest(topic) GA5	%	6.3%	18.8%	10.4%	45.8%	18.8%	100
	$\bar{x}$	3.52					
Importance GA	%	0%	2.1%	6.3%	47.9%	43.8%	100
	$\bar{x}$	4.33					
Interest (know+)GA	%	4.2%	16.7%	16.7%	43.8%	18.8%	100
	$\bar{x}$	3.56					
Agreement GA	%	12.5%	12.5%	25.0%	29.2%	20.8%	100
	$\bar{x}$	3.33					
Probability GA	%	8.3%	27.1%	31.3%	31.3%	2.1%	100
	$\bar{x}$	2.92					

Table 8: Frequency of engagement and interaction variables TA section - anisakis.

		1	2	3	4	5	
Interest(topic) TA	%	12.8%	21.3%	21.3%	36.2%	8.5%	100
	$\bar{x}$	3.06					
Importance TA	%	0%	8.5%	8.5%	46.8%	36.2%	100
	$\bar{x}$	4.11					
Interest (know+)TA	%	12.8%	14.9%	23.4%	40.4%	8.5%	100
	$\bar{x}$	3.17					
Agreement TA	%	21.3%	17.0%	17.0%	27.7%	17.0%	100
	$\bar{x}$	3.02					
Probability TA	%	19.1%	36.2%	29.8%	10.6%	4.3%	100
	$\bar{x}$	2.45					

In both tables the frequency (%) is calculated based on N=48 and N=47, respectively. The mean ($\bar{x}$) represents the mean value of the options selected (1 to 5). In the Interest(topic) and Interest (Know+) variables, for both the GA and TA, 1 correspond to "Not interested at all"; 2 to "Not very interested"; 3 to "Indifference"; 4 to "Interested"; 5 to "Very interested". In the Importance variable, for both the GA and TA, 1 correspond to "Not important at all"; 2 to "Of little importance"; 3 to "Moderately important"; 4 to "Important"; 5 to "Very important". In the Agreement variable, for both the GA and TA, 1 correspond to "Totally disagree"; 2 to "Partially disagree"; 3 to "Neither agree to disagree"; 4 to "Partially agree"; 5 to "Totally agree". Finally, in the probability variable, for both the GA and TA, 1 corresponds to "Impossible"; 2 to "Unlikely"; 3 to "Likely"; 4 to "Very likely"; 5 to "Certain".

To understand how the participants engage and interact with the GAs and the TAs, we performed similar analyses between all the variables. For the sake of simplicity and considering the similarity of the analyses performed on the considered variables, these results will be presented and discussed together in this section. Table 8 illustrates the GA results of the descriptive analysis of the considered variables: interest in the topic; importance to a wider field; interest in knowing more; agreement to read the complete article; and likelihood of interaction in social networks. Table 9 represents the same results concerning the TA. As all of these variables are measured using a Likert scale, and to simplify the interpretation and reduce the density of the tables, the numerical scale (1 to 5) is used. Although the numerical scale does not correspond exactly to the specific labels of each alternative option, the numerical ordination (1 to 5) represents the same relative order of the response options for all variables (Hill, 2008; Pal, 2015).

Regarding the GAs, the majority of the participants rated their interest in the topic as high, with 45.8% selecting “interesting” and 18.8% selecting “very interesting”. The same does not happen with the TAs, where the distribution was more evenly spread across the scale, with 21.3% of the participants selecting “not interested”, 21.3% selecting “indifferent”, and 36.2% selecting “interested”. Accordingly, the participants also tended to assign more importance to the topic when it was presented in GA format, with 47.9% selecting “important” and 43.5% selecting “very important”. While with the TA the participants also considered the topic important, the spread was slightly lower, with 40.4% selecting “important” and 36.2% selecting “very important”. The participants also revealed more interest in knowing more about the topic when the GA was presented, with 62% affirming to be “interested” or “very interested” in the GA, contrasting with the 48% provided by the TA element. Furthermore, the participants were revealed to be slightly reluctant to read the complete article independently of the type of abstract (50% of the participants totally or partially disagree or represent a neutral position with the GA and 55.3 with the TA). Despite that, with the GA, they seem to agree more with that possibility (50% selecting a positive position with the GA and 44.7% with the TA). Finally, regarding social media interaction, there is a clear tendency to interact more with the GA (33.4% with the GA and 14.9 with the TA) among the participants, not devaluating the fact that a relatively high proportion of participants do not believe to be likely to interact with either the GA nor the TA (35.4% and 55.3%, respectively).

After the descriptive analysis of all variables, the research team performed a normality test to ensure the non-normal distribution of each variable. This step was taken because, in general, it is common practice to use parametric tests in the case of evaluation scales if their distribution is close enough to the normal distribution (Hill, 2008). To access these, and taking into consideration the sample size, we performed

Shapiro-Wilk tests. All p-values are less than 0.05 (p-value < 0.001 for all variables); thus, the null hypothesis (normality) was rejected in all, leading us to conclude that all the variables were not normally distributed. There were clear differences identified between GA and TA results during the descriptive analysis. To understand if the differences were significant, we opted to use the non-parametric Wilcoxon ranks test. The results are illustrated in Table 10.

Table 10: Significance of the differences between GA and TA in engagement and interaction variables - anisakis.

GA - TA	Ranks	Z	p-value
Interest (topic)	Negative: 9[a]	2.551	0.011
	Positive: 20[b]		
	Ties: 18[c]		
Importance	Negative: 3[a]	2.399	0.016
	Positive: 12[b]		
	Ties: 32[c]		
Interest (know+)	Negative: 1[a]	3.082	0.002
	Positive: 13[b]		
	Ties: 33[c]		
Agreement	Negative: 1[a]	2.539	0.011
	Positive: 9[b]		
	Ties: 37[c]		
Probability	Negative: 2[a]	3.508	<0.001
	Positive: 18[b]		
	Ties: 27[c]		

Z is the statistical test employed and is based on the positive ranks. Ranks are calculated based on:

a. GA < TA; b. GA > TA; c. GA=TA

All the differences determined between GA and TA for each of the considered variables were found to be significant, as the p-values obtained were all smaller than 0.05. Thus, the results demonstrate a significant preference for GAs over TAs across all measured variables. Participants found the GA more engaging, better at transmitting the importance of the topic, and more likely to stimulate further interest and interaction. One notable aspect of the results is the high number of ties in each variable, indicating that a significant portion of participants rated the GA and the TA equally. This suggests that while a considerable number of participants did not perceive a difference between the GA and the TA at a certain level, those who did perceive a difference reflected a significant preference for the GA. In this context, it is important to acknowledge that it is impractical for any communication tool to appeal to an entire population uniformly, especially in science communication (Cooke et al., 2017). However, the key aspect to acknowledge is that the portion of the population that is impacted by the scientific tool is positively impacted, as is in this specific case.

Having determined the existence of a significant difference between GA and TA on the considered variables, it was decided by the research team that the next step should be to calculate the size of that difference, to understand the dimension of the impact caused by the GA element. To achieve this, we decided to represent the percentage increase between the means of GA and TA values for each variable. This calculation involved determining how much one value (GA) has increased relative to the other (TA). We started by finding the difference between the two values and then standardizing the initial value (considered to be the TA in this case). The results were calculated following the equation below:

$$Increase\ with\ GA\ (\%) = \left(\frac{MeanGA\ - MeanTA}{Mean\ TA}\right) * 100$$

The results are illustrated in Table 11.

Table 11: Increase (%) of each variable - anisakis.

GA-TA (%)	**Interest (topic)**	**Importance**	**Interest (know+)**	**Agreement**	**Probability**
Increase (%)	+15.03%	+5.35%	+12.30%	+10.27%	+19.18%

In every variable, a significant increase was detected. Participants' interest in the topic increased by 15% when the topic was presented in GA format. Similarly, the GA showed a 12.30% increase in the interest of the participants to know more about the topic. This suggests that the *Anisakis* GA is more effective at not only capturing and maintaining participants' interest in the topic but also at stimulating curiosity and desire to be better informed. Regarding the importance assigned to the topic covered on the

GA and the TA, the participants tended to consider the topic important either way, which was expected because it directly impacts public health. Notwithstanding, there was an increase of 5.35%, revealing that with the GA the participants tended to consider the topic even more important. Thus, the GA was better at impacting the participants, leading them to value the topic more.

Surprisingly, the increase concerning the agreement of reading the complete scientific article was around 10%, when comparing the GA to the TA. Generally, there is high public resistance to reading a complete scientific article (Elena Zudilova-Seinstra, 2014). Therefore, the observed increase was larger than expected before the study. This could be because the GA provided a clear and appealing overview of the topic, making the full article seem more approachable and worth the time investment. Despite this, it is important to note that the present sample revealed a considerably high frequency of reading scientific articles, as shown in chart 4. This might have contributed to the observed increase, particularly if the increase was centred among the participants who already read articles frequently, or very frequently. This potential influence of reading frequency on the increase underscores the need for further analysis to fully understand the impact. Considering this, we conducted a Kruskal-Wallis H test to determine if there were significant differences in the increased agreement between the GA and TA across the different frequencies of reading. The results are illustrated in Table 12.

Table 12: Kruskal-Wallis H test results (reading frequency / agreement) – anisakis.

Kruskal-Wallis test

Pearson's chi square: 12.921

Degrees of freedom: 4

p-value = 0.012

	Reading frequency *	**N**	**Mean Rank**
GA - TA	**Never**	2	20.00
	Rarely	8	25.56
	Occasionally	12	31.86
	Frequently	16	21.28
	Very frequently	9	17.89

The results indicate that the frequency with which participants read scientific articles does influence the increase reported before. Nevertheless, the results suggest that the participants who read scientific articles frequently (mean rank = 21.28) and very frequently (mean rank = 17.89) have lower mean ranks, suggesting a smaller increase in agreement with the GAs compared to TAs. Thus, in participants who already tend to read articles the impact is less pronounced, probably because these participants are already accustomed to engaging with TAs and may not require additional visual stimulation to be motivated to read the full article. As the highest impact of GAs is seen among participants who read articles occasionally, the results suggest that GAs may be particularly effective in engaging individuals who are not regular readers of scientific literature, potentially encouraging them to read more. Likewise, despite the influence of reading frequency in the increase registered, it is still significant because its main effect is on participants who don't read scientific articles frequently.

Finally, the GA produced an increase of almost 20% regarding the probability of interaction with the element in social networks. This is the highest increase among the variables, suggesting that the GA is particularly effective in encouraging digital interactions. Considering the general visual nature of social networks, visually engaging content is likely more sharable (Ibrahim et al., 2017). Thus, the high impact of the GA was expected before the study, which the data supports. Despite that, it is commonly known that depending on the age, each person interacts differently with social networks, namely social media. Considering this, we conducted the Kruskal-Wallis H test to determine if there were significant differences in the increased probability of interaction between the GA and TA across the different age groups. The results are shown in Table 13, where it is possible to understand that there is not a significant influence of age on interaction in social media. This is positive because it suggests that the GA increases the probability of interaction in social networks across all age groups.

Table 13: Kruskal-Wallis H test results (age/probability).

Kruskal-Wallis test
Pearson's chi square: 4.241
Degrees of freedom: 5
p-value = 0.515

	Probability interaction	**N**	**Mean Rank**
GA - TA	**18-24**	15	28.47
	25-34	15	20.80
	35-44	3	22.50
	45-54	8	25.75
	55-64	5	19.90
	65 +	1	16.00

III. Comprehension

To finalize the analysis of the *Anisakis* section, we intended to understand the impact of the GA on the comprehension of the topic addressed. As described before, in both the GA and TA subsections, two questions were made in this regard, one asking about the objective of the study (question 1) and the other about its main findings (question 2). Each question had four possible answers provided and only one was the correct one. The descriptive results of both subsections are illustrated in Table 14.

Table 14: GA and TA frequency results on comprehension - *anisakis*.

GA	Correct (%)	Incorrect (%)
Question 1	43.8	18.8+2.1+35.4
Question 2	64.6	33.3+2.1+0

TA	Correct (%)	Incorrect (%)
Question 1	63.8	29.8+2.1+4.3
Question 2	76.6	12.8 + 8.5 +2.1

The frequency of the incorrect results is represented by the sum of the frequencies of the three wrong alternative options provided.

At first sight, the frequency results show a higher rate of correct answers when the information is presented in TA format. To further discuss this, it was necessary to understand if these differences were statistically significant. As for the binary nature of these variables, we decided to perform a McNemar test. Table 15 and Table 16 illustrate the results obtained for questions 1 and 2, respectively.

Table 15: Comprehension results of question 1 - anisakis.

Question 1 GA \ Question 1 TA	✗	✓	T_{GA}
✗	11	15	26
✓	6	15	21
T_{TA}	17	30	47

McNemar test

p-value = 0.078

Table 16: Comprehension results of question 2 - *anisakis*.

		Question 2 TA		
		✗	✓	T_{GA}
Question 2 GA	✗	8	10	18
	✓	3	26	29
	T_{TA}	11	36	47

McNemar test
p-value = 0.092

Despite the descriptive statistics showing a higher percentage of correct answers for TAs, the McNemar test results indicate that these differences are not statistically significant at the 0.05 level for both of the questions. This suggests that while there appears to be a tendency for better comprehension with TAs, the data does not provide strong enough evidence to confirm that difference. Considering these results there are some points to be noted. Firstly, there is no doubt that the TA is the primary source of the information. Thus, the level of comprehension with the GA was not expected to surpass the level of comprehension with the TA. Likewise, when applying this type of scientific communication tool, the valuable aspect is that the level of comprehension remains the same and does not decrease, which happens in this case because the differences found favouring TAs are not significant in this context. Secondly, the GA objectives do not refer to their impact on comprehension, focusing instead on their impact on engagement and raising awareness (Nikolian & Ibrahim, 2017), which was indeed found relevant in the previous analysis. Nevertheless, if a decrease in the level of comprehension was significant it could be a serious implication in the application of GAs as scientific communication tools. It is also important to consider possible limitations inherent in the study which might lead to these results, such as the quality of the details given in the GA to ensure the comprehension of the topic, the formulation of the questions made; the potential impact that the prior knowledge of the participants might have in their comprehension. These aspects highlight the need to further investigate this topic.

4.2.2. Microplastics article

Seventy-nine participants were assigned to the microplastics article. Out of these, eleven are incomplete answers. Five participants answered only the GA subsection, four participants answered only the TA subsection, and the other two completed both subsections but did not answer the final question. The variables analysed in this context are the same as the previous article: a first impression; interest in the topic; comprehension; importance to a wider field; interest in knowing more; agreement to read the complete article; and likelihood of interaction in social networks.

I. First impression

Regarding the first impression of the participants towards the GA and the TA, the same categorization of the *Anisakis* article was made, considering the following categories: positive, negative, neutral, feelings on the topic (both positive and negative feelings), and scientific related. For further information on categorization see Attachment [4]. Chart 9 shows the distribution of the frequency of each category, both for the GA and the TA subsections.

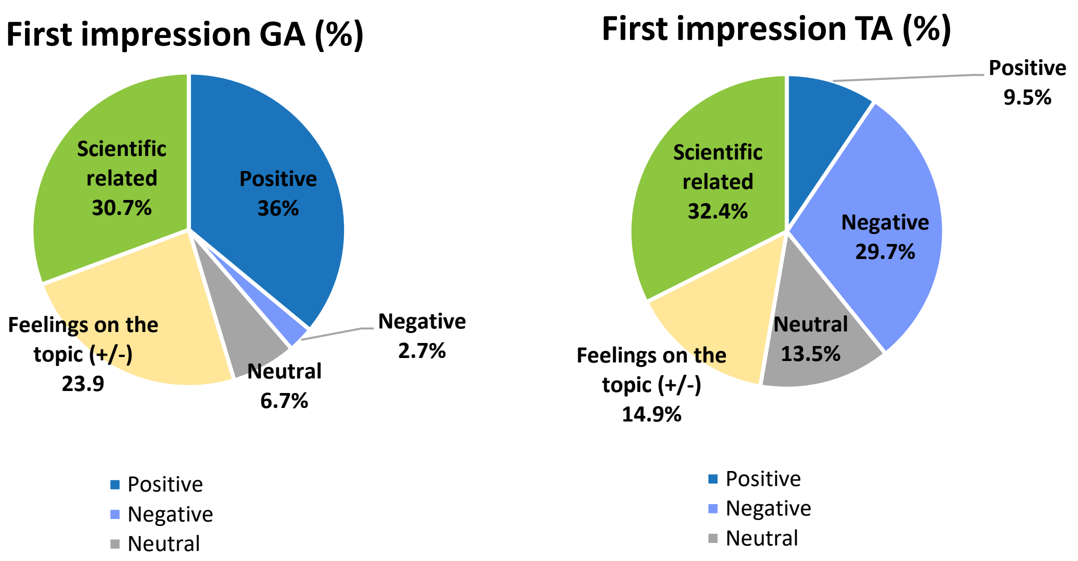


Chart 9: Frequency of 1st impression categories GA and TA – microplastics.

It is clear that when compared to TAs, GAs received a significantly higher proportion of positive first impressions, namely 36% positive impressions towards the GA opposing to 9.5% positive impressions towards the TA. The GA received a low number of negative impressions (2.7%) contrasting to the almost 30% of the TA. Similarly to the *Anisakis* article, the GA tended to polarize first impressions more towards positive or negative, with fewer neutral responses, suggesting its advantage when it comes to quickly connecting with the public (Fischhoff, 2013). It is important to note the substantial number of participants, both in the GA (30.7%) and in the TA (32.4%), that referred to a first impression related to the scientific topic itself.

Table 17 shows the distribution of first impressions categories for the GA in comparison to the TA, representing in each cell, the specific first impression for both GAs and TAs. Additionally, a chi-square test was performed to assess the association between both variables. This test allows us to identify if the differences found are statistically significant. The p-value obtained (<0.001) indicates, that similarly to the *Anisakis* article, in the microplastics article the association between the type of abstract and the first impression categories, is statistically significant. This suggests that the type of abstract influences how participants perceive the content at first glance. Therefore, the results of the first impression analysis, support the previous statement that GAs engage readers quickly and more effectively than TAs, potentially making them more effective for communicating scientific information to a broader audience (J.E. Thomas, 2006).

Table 17: Crosstable GA and TA 1st impression – microplastics.

Chi-square test

Pearson's chi square: 52.518

Degrees of freedom: 16

p-value = <0.001

Categories GA (1st imp.) \ Categories TA (1st imp.)	P(+)	N(-)	N(0)	FT	SR	N_{TTA}
P(+)	3	14	6	3	1	27
N(-)	0	1	0	0	1	2
N(0)	1	0	1	0	2	4
FT	2	4	0	7	3	16
SR	0	1	2	1	17	21
N_{TGA}	6	20	9	11	24	70

Categories: P (+) – positive; N (-) – Negative; N (0) – Neutral; FT – Feelings on the topic; SR – Scientific Related.

II. Engagement and interaction

Following the structure of the *Anisakis* article analysis, the results evaluating engagement and interaction will be presented and discussed together in this section. Table 18 and Table 19 illustrate the results obtained by descriptive analysis of the GA and TA elements, respectively. These tables follow the structure described before for tables 8 and 9 in the *Anisakis* article section.

Table 19: Frequency of engagement and interaction variables GA section - microplastics.

		1	2	3	4	5	
Interest(topic) GA5	%	0%	9.3%	6.7%	60.0%	24.0%	100
	$\bar{x}$	3.99					
Importance GA	%	0%	4%	5.3%	44.0%	46.7%	100
	$\bar{x}$	4.33					
Interest (know+)GA	%	0%	6.7%	9.3%	64.0%	20%	100
	$\bar{x}$	3.97					
Agreement GA	%	2.7%	10.7%	14.7%	36.0%	36.0%	100
	$\bar{x}$	3.92					
Probability GA	%	2.7%	28.0%	32.0%	32.0%	5.3%	100
	$\bar{x}$	3.09					

Table 18: Frequency of engagement and interaction variables TA section - microplastics.

	1	2	3	4	5	
Interest(topic) TA	0%	21.6%	4.1%	63.5%	10.8%	100
	3.64					
Importance TA	0%	4.1%	10.8%	37.8%	47.3%	100
	4.28					
Interest (know+)TA	0%	10.8%	10.8%	60.8%	17.6%	100
	3.85					
Agreement TA	5,4%	18.9%	14.9%	37.8%	23%	100
	3.54					
Probability TA	8.1%	35.1%	27.0%	24.3%	5.4%	100
	2.84					

In both tables the frequency (%) is calculated based on N=75 and N=74, respectively. The mean ($\bar{x}$) represents the mean value of the options selected (1 to 5). In the Interest(topic) and Interest (Know+) variables, for both the GA and TA, 1 correspond to "Not interested at all"; 2 to "Not very interested"; 3 to "Indifference"; 4 to "Interested"; 5 to "Very interested". In the Importance variable, for both the GA and TA, 1 correspond to "Not important at all"; 2 to "Of little importance"; 3 to "Moderately important"; 4 to "Important"; 5 to "Very important". In the Agreement variable, for both the GA and TA, 1 correspond to "Totally disagree"; 2 to "Partially disagree"; 3 to "Neither agree to disagree"; 4 to "Partially agree"; 5 to "Totally agree". Finally, in the probability variable, for both the GA and TA, 1 corresponds to "Impossible"; 2 to "Unlikely"; 3 to "Likely"; 4 to "Very likely"; 5 to "Certain".

In general, the results of the descriptive analysis of the microplastics article for both the GA and the TA elements were considered to be high (on the positive pole). For example, in the interest on the topic variable, there is a difference between the GA and TA mean interest level, but both of the values are high due to the elevated frequency of “interested” and “very interested” in both the GA (84%) and the TA (74.3%). Nevertheless, there is a difference in favouring the GA. The participants found the topic equally important, with the frequency of important and very important together reaching 90% in the GA and almost the same value for the TA. Despite that slightly higher impact for the GA, both elements also stimulated interest in further information. The bigger differences between the GA and the TA happened in the agreement and probability categories. In the first case, while 36% of the participants agreed to the possibility of reading the complete article with the GA, only 23% said the same with the TA. Despite that, it is important to note that the level of agreement was higher than expected for both the elements, especially when compared to the *Anisakis* results ($GA_{MP's}$ = 3.92 vs GA_{ani} = 3.33 and $TA_{MP's}$ = 3.54 and Ta_{ani} = 3.02). Finally, in the probability variable, the participants showed a 37.3% probability of interaction (“very likely” and “certain”) with the GA, and a 29.4% probability of interaction (“very likely” and “certain”) with the TA.

After the descriptive analysis of all variables, the research team performed a normality test to ensure the non-normal distribution of each variable, which was verified (p-value < 0.001 for all variables). Next, we performed the non-parametric Wilcoxon ranks test to determine if the differences found during the descriptive analysis were statistically significant. The results are illustrated in Table 20.

Table 20: Significance of the differences between GA and TA in engagement and interaction variables - microplastics.

GA - TA	Ranks	Z	p-value
Interest (topic)	Negative: 3[a] Positive: 23[b] Ties: 44[c]	3.579	<0.001
Importance	Negative: 6[a] Positive: 10[b] Ties: 54[c]	1.147	0.251
Interest (know+)	Negative: 4[a] Positive: 15[b] Ties: 51[c]	2.180	0.029
Agreement	Negative: 2[a] Positive: 20[b] Ties: 48[c]	3.731	<0.001
Probability	Negative: 3[a] Positive: 21[b] Ties: 46[c]	3.252	<0.001

Z is the statistical test employed and is based on the positive ranks.
Ranks are calculated based on:
a. GA < TA; b. GA > TA; c. GA=TA

The results regarding the importance of the topic to a wider field are particularly noteworthy. The analysis indicates that there was no statistically significant difference (p-value = 0.251) in how important participants found the topic when presented with the GA compared to the TA. Despite this, participants rated the importance of the topic as high in both formats. This outcome suggests that prior knowledge and awareness of the participants about the topic may have influenced the results. The article focuses on microplastics, pollution, and the impact of climate change, which are highly relevant and frequently discussed topics in society today. It is plausible that participants were already aware of and informed about the importance of these issues before the study, thereby minimizing the impact that the GA could have had in changing their perception of the topic's importance. This finding highlights the necessity for further research to explore this question in more detail. However, it is important to note that even with such a general and well-known topic, GAs had a significant impact on all other evaluated variables, with p-values < 0.029. The results demonstrate a significant preference for GAs over TAs across the distinct variables considered. Similarly to the *Anisakis* article, the participants found the GA more engaging, and likely to stimulate further interest and interaction. The high number of ties observed in each variable is similar to the *Anisakis* article. Once more his high number of ties may indicate that while some participants have a strong preference for one format over the other, many found no difference between them.

Having determined the existence of significant differences between GA and TA on some of the considered variables, it was decided by the research team that the next step should be to calculate the size of that difference, to understand the dimension of the impact caused by the GA element. This was done following the method employed in the *Anisakis* article Analysis, based on the equation:

$$Increase\ with\ GA\ (\%) = \left(\frac{MeanGA\ - MeanTA}{Mean\ TA}\right) * 100$$

The results are illustrated in Table 21.

Table 21: Increase (%) of each variable - microplastics.

GA-TA (%)	Interest (topic)	Importance	Interest (know+)	Agreement	Probability
Increase (%)	+9.6%	~~+1,16%~~*	+3.11%	+10.74%	+8.80%

***this value was not considered because the difference found was not significant.

The participants' interest in the topic increased by approximately 10% when the topic was presented in GA format. Similarly, the GA showed a significant increase of 3% in the interest of the participants to know more about the topic. This suggests that the Microplastics GA captures and maintains more effectively the participants' interest in the topic. The stimulus to know more about the topic is still significant in this context, however, if we compare it with the *Anisakis* results for this variable, there is a significant decrease. Once more, the fact that the population is well informed on this topic might impact this, because the participants might consider that there is not anything else to know about the topic.

Consistently with the *Anisakis* results, the increase concerning the agreement of reading the complete scientific article was around 10% more with the GA compared to the TA. This result was larger than expected before the study, due to the resistance of the public to read full scientific articles (Elena Zudilova-Seinstra, 2014). A similar analysis to the one done in the *Anisakis* section was performed to assess if the frequency of reading had or not an impact in this case. The results of the Kruskal-Wallis H test are described in Table 22.

Table 22: Kruskal-Wallis H test results (reading frequency/ agreement) – microplastics.

Kruskal-Wallis test
Pearson's chi square: 1.320
Degrees of freedom: 3
p-value = 0.724

	Reading frequency *	**N**	**Mean Rank**
GA - TA	**Never**	0	
	Rarely	16	32.97
	Occasionally	19	36.42
	Frequently	23	38.02
	Very frequently	12	32.58

The results in Table 22 show that the frequency of reading scientific articles did not significantly impact the increase in agreement to read the complete article when presented with GAs compared to TAs. Therefore, it is likely that the clear and appealing overview of the topic, together with the probable increased curiosity due to the prior knowledge of the participants, contributed to this increase.

Concerning the probability of interaction with the graphic element, an increase of 8.8% was registered with the GA format. However, it is notable that a significant decrease happened when comparing the result with the correspondent one on the *Anisakis* article analysis (19.18%). Once more, this difference might be due to the nature of the scientific topic in analysis. As all the results presented here appear to have a factor influencing them, further research is necessary to understand the impact of the nature of the scientific topic in the present social context. Evaluating the impact of GA across different scientific topics might help clarify this question.

Similarly to the procedure followed in the *Anisakis* article, we considered it relevant to understand the influence of age in this variable. Table 23 reports the results obtained. Once more there is not a significant influence of age on the interaction in social media. Equally to the *Anisakis* article, this is positive because it suggests that the GA increases the probability of interaction in social networks across all age groups.

Table 23: Kruskal-Wallis H test results (age/probability) - microplastics.

Kruskal-Wallis test
Pearson's chi square: 7.534
Degrees of freedom: 5
p-value = 0.184

	Probability interaction *	N	Mean Rank
GA - TA	**18-24**	18	28.47
	25-34	17	20.80
	35-44	8	22.50
	45-54	11	25.75
	55-64	13	19.90
	65 +	3	16.00

III. Comprehension

To finalize the analysis of the microplastics section, we intended to understand what the impact of the GA was on the comprehension of the topic addressed. The structure of the questions asked, and the analysis done are the same as performed in the *Anisakis* article section. The descriptive results of both subsections (GA and TA) are illustrated in Table 24.

Table 24: GA and TA frequency results on comprehension - microplastics.

GA	Correct (%)	Incorrect (%)
Question 1	72.0	0+12.0+16.0
Question 2	73.3	1.3+16.0+9.3

TA	Correct (%)	Incorrect (%)
Question 1	70.3	0+14.9+14.9
Question 2	74.3	0+17.6+8.1

The frequency of the incorrect results is represented by the sum of the frequencies of the three wrong alternative options provided.

The results reported in Table 24 show that the differences between GA and TA are minimal, suggesting the participants had similar comprehension levels for both formats. Even so, we conducted a McNemar test to understand if there was any significant difference between the variables. The results are in Tables 25 and Table 26 (questions 1 and 2, respectively).

Table 25: Comprehension results of question 1 - microplastics.

Question 1 GA \ Question 1 TA	✗	✓	T_{GA}
✗	11	7	18
✓	10	42	52
T_{TA}	21	49	70

McNemar test

p-value = 0.629

Table 26: Comprehension results of question 2 - microplastics.

Question 2 GA \ Question 2 TA	✗	✓	T_{GA}
✗	12	6	18
✓	6	46	52
T_{TA}	18	52	70

McNemar test

p-value = 0.999

The McNemar test results do not highlight any significant differences in the level of comprehension between the GA and the TA for both questions. Thus, the proportions of correct and incorrect answers did not change significantly between the two formats. Indeed, the majority of the participants answered both questions correctly, revealing that there was not a decrease in the comprehension level, as was intended. These results are consistent with the previous findings for the *Anisakis* article, supporting that opting between GAs and TAs can be based on other factors, such as audience, preference or engagement, without compromising comprehension.

4.2.3. Seahorse article

Eighty-seven participants were assigned to the seahorse article. Out of these, six are incomplete answers. Four participants answered only the GA subsection, two participants answered only the TA subsection. The variables analysed in this context are the same as the previous articles: first impression; interest in the topic; comprehension; importance to a wider field; interest in knowing more; agreement to read the complete article; and likelihood of interaction in social networks.

I. First impression

Regarding the first impression of the participants towards the GA and the TA, the same categorization of the *Anisakis* article was made, with the following categories: positive, negative, neutral, feelings on the topic (both positive and negative feelings), and scientific related. For further information on categorization see Attachment [5]. Chart 10 shows the distribution of the frequency of each category, both for the GA and the TA subsections.

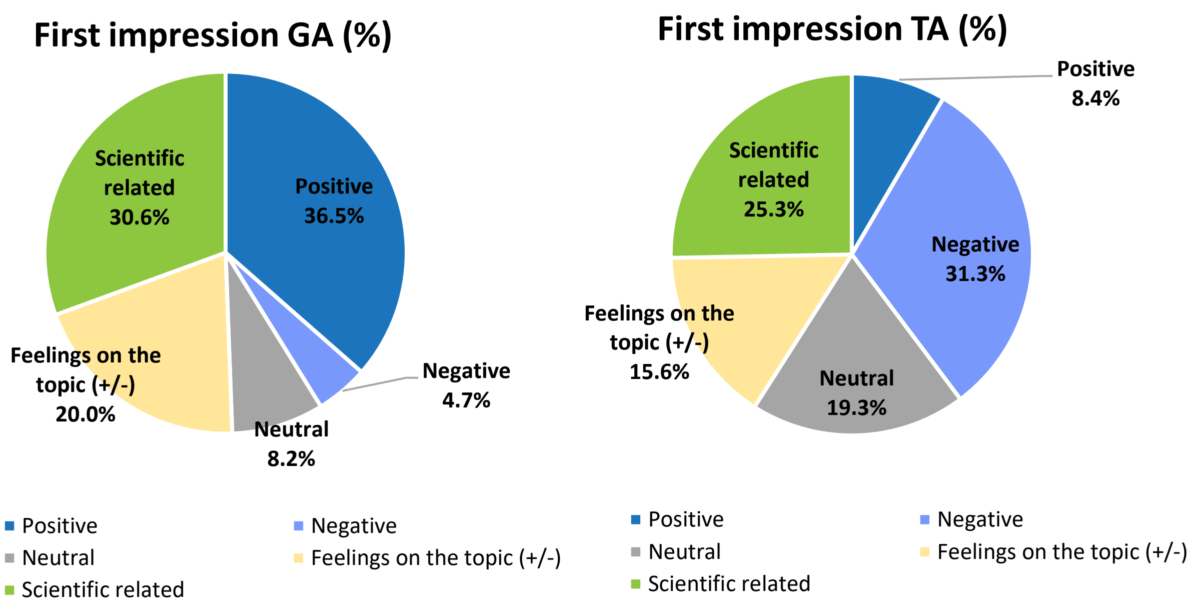


Chart 10: Frequency of first impression categories GA and TA - seahorse.

The GAs received a significantly higher proportion of positive first impressions, namely 36.5% positive impressions towards the GA opposing to 8.4% positive impressions towards the TA. The GA received a low number of negative first impressions (4.7%), contrasting with more than 30% for the TA. Similarly to both previous articles, the GA tended to polarize first impressions leading the participants to opt more towards positive or negative answers, with fewer neutral responses, suggesting its advantage when it comes to quickly connecting with the public (Fischhoff, 2013). The results support the positive impact of GAs. Both formats had a substantial number of participants who defined their first impression within the scientific-related category.

Consistently to the previous analyses, Table 27 shows the distribution of first impressions categories for the GA in comparison to the TA, representing in each cell, the specific first impression for both GAs and TAs. Additionally, a chi-square test was performed to assess the association between both variables.

Table 27: Crosstable GA and TA 1st impression - seahorse.

Chi-square test

Pearson's chi square: 57.894

Degrees of freedom: 16

p-value = <0.001

Categories GA (1st imp.) \ Categories TA (1st imp.)	P(+)	N(-)	N(0)	FT	SR	NTTA
P(+)	4	15	4	6	1	30
N(-)	0	1	1	1	0	3
N(0)	1	2	4	0	0	7
FT	1	7	2	5	1	16
SR	0	1	5	1	17	24
NTGA	6	26	16	13	19	80

Categories: P(+) – positive; N(-) – Negative; N(0) – Neutral; FT – Feelings on the topic; SR – Scientific Related.

The p-value obtained in the chi-square test (<0.001) indicates that, similarly to the *Anisakis* and microplastics articles, the association between the type of abstract and the first impression categories is statistically significant. Once more, this suggests that the type of abstract influences how participants perceive the content at first glance. Therefore, the results of the first impression analysis, support the previous statement that GAs engage readers quickly and more effectively than TAs, potentially making them more effective for communicating scientific information to a broader audience (J.E. Thomas, 2006).

II. Engagement and interaction

As in the previous sections, the results concerning engagement and interaction will be presented and discussed together in this section. Tables 28 and 29 present descriptive statistics for the considered variables comparing the GA and the TA. These tables follow the structure described before for tables 8 and 9 in the *Anisakis* article section.

Table 29: Frequency of engagement and interaction variables GA section - seahorse.

		1	2	3	4	5	
Interest(topic) GA5	%	10.8%	28.9%	14.5%	42.2%	3.6%	100
	$\bar{x}$	2.96					
Importance GA	%	2.4%	12.9%	25.9%	40.0%	18.8%	100
	$\bar{x}$	3.60					
Interest (know+)GA	%	11.8%	23.5%	25.9%	34.1%	4.7%	100
	$\bar{x}$	2.96					
Agreement GA	%	15.3%	18.8%	27.1%	25.9%	12.9%	100
	$\bar{x}$	3.02					
Probability GA	%	5.9%	38.8%	36.5%	16.5%	2.4%	100
	$\bar{x}$	2.71					

Table 28: Frequency of engagement and interaction variables TA section - seahorse.

		1	2	3	4	5	
Interest(topic) TA		18.1%	28.9%	20.5%	32.5%	0%	100
		2.67					
Importance TA		2.4%	19.3%	24.1%	45.8%	8.4%	100
		3.39					
Interest (know+)TA		18.1%	26.5%	21.7%	32.5%	1.2%	100
		2.72					
Agreement TA		24.1%	18.1%	24.1%	24.1%	9.6%	100
		2.77					
Probability TA		9.6%	56.6%	25.3%	8.4%	0%	100
		2.33					

In both tables the frequency (%) is calculated based on N=85 and N=83, respectively. The mean ($\bar{x}$) represents the mean value of the options selected (1 to 5). In the Interest(topic) and Interest (Know+) variables, for both the GA and TA, 1 correspond to "Not interested at all"; 2 to "Not very interested"; 3 to "Indifference"; 4 to "Interested"; 5 to "Very interested". In the Importance variable, for both the GA and TA, 1 correspond to "Not important at all"; 2 to "Of little importance"; 3 to "Moderately important"; 4 to "Important"; 5 to "Very important". In the Agreement variable, for both the GA and TA, 1 correspond to "Totally disagree"; 2 to "Partially disagree"; 3 to "Neither agree to disagree"; 4 to "Partially agree"; 5 to "Totally agree". Finally, in the probability variable, for both the GA and TA, 1 corresponds to "Impossible"; 2 to "Unlikely"; 3 to "Likely"; 4 to "Very likely"; 5 to "Certain".

The majority of the participants rated the interest as moderate to high with the GA element, as 42.2% answered “interested”. The same option with the TA presented a frequency of 32.5%. Nevertheless, it is important to note that the frequency of the option “not very interested” was 28.9% for both the GA and TA formats. This tendency shows a relevant impact on the GA. However, it reflects a possible decrease in the general interest in the topic, when compared to the previous articles. Regarding, the importance attributed to the topic in a wider field, the participants considered the topic to be relatively important, being noticeable a general decrease compared to the *Anisakis* and microplastics articles. Either way, the impact of the GA was noticeable. Namely, 58.8% of the participants considered the topic important with the GA (“important” + “very important”), while only 54.2% considered the same with the TA. Additionally, the GA led more participants to take a positive stronger position (18.8% vs 8.4%). The participants seemed hesitant when it comes to knowing more about the topic, with more than 60% of the participants reporting having a negative or neutral position in both the GA and TA formats. Even so, the interested participants reported to be more interested with the GA format than the TA. For the agreement and probability variables, the tendency of general lower scores for both formats with a slightly higher preference for the GA is maintained. The general tendency of lower scores for both formats is probably due to the nature of the scientific topic itself, as genetics is typically a more abstract and complex field. As has been explained before, the decision to include this article was made to understand the strength of the GA impact even in more complex topics, in which the impact on society might not be so clear. This is important as the scientific research goes from the most specific molecule to the most general environmental problem, thus evaluating the range of impact of this scientific tool might be an advantage in its future implementation.

After an evaluation of normality to understand the significance of the differences found in the descriptive analysis, we followed the same methods used in the previous articles and performed a non-parametric Wilcoxon ranks test, which the results are illustrated in Table 30.

Table 30: Significance of the differences between GA and TA in engagement and interaction variables - seahorse.

GA - TA	Ranks	Z	p-value
Interest (topic)	Negative: 7[a] Positive: 29[b] Ties: 45[c]	2.537	0.011
Importance	Negative: 9[a] Positive: 21[b] Ties: 51[c]	2.148	0.032
Interest (know+)	Negative: 9[a] Positive: 25[b] Ties: 47[c]	2.706	0.007
Agreement	Negative: 5[a] Positive: 25[b] Ties: 51[c]	3.073	0.002
Probability	Negative: 2[a] Positive: 29[b] Ties: 50[c]	4.338	<0.001

Z is the statistical test employed and is based on the positive ranks.
Ranks are calculated based on:
a. GA < TA; b. GA > TA; c. GA=TA

All the differences found are statistically significant, with the GA being found to be more interesting and better at stimulating further interest, leading to a higher valorisation of the topic, a higher rate of agreement to read the complete article and a significantly increased likelihood of interaction in social networks. Nevertheless, across all variables, there is a notable number of ties, indicating that a significant portion of participants rate the GA and TA equally. This is consistent with the results observed in the *Anisakis* and microplastics articles, supporting the GAs advantages reported in the literature in prior reviews and studies (Ibrahim, 2017; Ibrahim et al., 2017; Oska et al., 2020).

Having determined the existence of significant differences between GA and TA on some of the considered variables, the next step was to calculate the size of that difference, to understand the dimension of the impact caused by the GA element. This was done following the method employed in the *Anisakis* article analysis, based on the equation:

$$Increase\ with\ GA\ (\%) = \left(\frac{MeanGA\ - MeanTA}{Mean\ TA}\right) * 100$$

The results are presented in Table 31.

Table 31: Increase (%) of each variable - seahorse.

GA-TA (%)	Interest (topic)	Importance	Interest (know+)	Agreement	Probability
Increase (%)	+10.86%	+6.19%	+7.35%	+9.03%	+16.31%

The participants' interest in the topic increased by approximately 11% when the topic was presented in GA format. The visual appeal of the GA likely made it more engaging and accessible, capturing the audience's attention more effectively than the text alone. Similarly, the GA, showed a significant increase of 7.35% in the interest of the participants to know more about the topic, reflecting a stimulation of curiosity and encouraging further exploration due to their brief and visually engaging presentation.

Consistently with the *Anisakis* and microplastics results, the increase concerning the agreement of reading the complete scientific article was around 10% more with the GA compared to the TA. Besides consistency, this value is high, considering the reported resistance of the public to read full scientific articles (Elena Zudilova-Seinstra, 2014). Therefore, a similar analysis to the one done in the previous sections was performed to assess if the frequency of reading had or not an impact in this case. The results of the Kruskal-Wallis H test are described in Table 32.

Table 32: Kruskal-Wallis H test results (frequency of reading/ agreement) – seahorse.

Kruskal-Wallis test

Pearson's chi square: 3.431

Degrees of freedom: 4

p-value = 0.488

GA - TA	Reading frequency *	N	Mean Rank
	Never	4	48.50
	Rarely	5	40.50
	Occasionally	29	37.69
	Frequently	28	45.64
	Very frequently	15	36.90

The Kruskal-Wallis H test results show that the frequency of reading scientific articles did not significantly impact the increase in agreement to read the complete article when presented with GAs compared to TAs, in this particular case. Therefore, the results support that the clear and appealing overview of the topic in the GA was good enough to make the participants believe the article was worth the time investment. The contrary effect of the microplastics article might have happened here. While in the case of the microplastics article, it was likely that the participants had general high knowledge of the topic before the study, here the participants probably had little knowledge of the matter, thus the intrinsic curiosity of the human being might have played a role (McQuail, 2003).

Finally, the GA increased the likelihood of participants interacting with the content on social networks by 16.31%, which is an increase similar to the one reported in the *Anisakis* article. This might reflect a limitation on the increase reported in the microplastics article, as was discussed in that section. This higher probability of interaction suggests that GAs can play a crucial role in disseminating scientific information more widely and engaging a broader audience, known as some of the GA objectives (Ibrahim, 2017; Ibrahim et al., 2017). Nevertheless, the Kruskal-Wallis test between the age variables and the probability of interaction was conducted. The results are illustrated in Table 33. Once more, there is no association between the variables, reflecting the capacity of the GA to engage the participants of all age groups.

Table 33: Kruskal-Wallis H test results (age/probability) - seahorse.

Kruskal-Wallis test
Pearson's chi square: 7.534
Degrees of freedom: 5
p-value = 0.184

	Probability interaction *	**N**	**Mean Rank**
GA - TA	**18-24**	28	40.68
	25-34	17	46.71
	35-44	10	34.90
	45-54	15	41.70
	55-64	8	41.38
	65 +	3	27.50

III. Comprehension

As far as comprehension goes, we intend to understand the impact of the GA. The structure of the questions asked, and the analysis done is the same as performed in the Anisakis and microplastics articles section. The descriptive results of both subsections (GA and TA) are illustrated in Table 34.

Table 34: GA and TA frequency results on comprehension - seahorse.

GA	Correct (%)	Incorrect (%)
Question 1	62.4	2.4+29.4+5.9
Question 2	63.5	11.8+11.8+12.9

TA	Correct (%)	Incorrect (%)
Question 1	68.7	10.8+18.1+2.4
Question 2	68.7	8.4+13.3+9.6

The frequency of the incorrect results is represented by the sum of the frequencies of the three wrong alternative options provided.

The results shown in Table 34 are very similar to the ones found in the corresponding analysis concerning the microplastics and *Anisakis* articles. For both questions, the percentage of correct responses was higher for the TAs compared to the GAs. However, as is possible to see in Tables 35 and 36, the differences registered between the GA and TA are not statistically significant at the 0.05 level. Additionally, a significant number of participants answered correctly to both of the questions, indicating that the general level of understanding was relatively high. The results highlight the capacity of the GA to not compromise the comprehension of the participants and, at the same time boost their impact as a science communication tool.

Table 35: Comprehension results of question 1 - seahorse.

Question 1 GA \ Question 1 TA	✗	✓	T_{GA}
✗	12	18	30
✓	13	38	51
T_{TA}	25	56	81

McNemar test

p-value = 0.473

Table 36: Comprehension results of question 2 - seahorse.

		Question 2 TA		
		✗	✓	T_{GA}
Question 2 GA	✗	11	19	30
	✓	15	36	51
	T_{TA}	26	55	81

McNemar test
p-value = 0.608

4.2.4. Overall discussion (three articles)

The extensive analysis of the three articles – *Anisakis*, microplastics and seahorse illustrates a consistent pattern in favour of GAs over TAs across multiple dimensions relevant to science communication, supporting the effectiveness of the GAs as science communication tools.

Across all three articles, GAs consistently obtained a significantly higher proportion of positive first impressions compared to TAs. This highlights the inherent advantage of visual elements in capturing attention and making a strong initial impact, as was previously described in the literature ("Introduction to Visual Communication," 2014; Oska et al., 2020). In the context of science communication, first impressions are crucial to capture the audience to reach further engagement (Franconeri et al., 2021). GAs, with their visually appealing format, make scientific content more accessible and inviting (J.E. Thomas, 2006), encouraging the audience to delve deeper into the scientific topic.

Participants revealed higher interest (weighted average increase = 11.05%) in the scientific topic when presented with the GA in all three articles. This increase in interest suggests that GAs are particularly effective in stimulating curiosity and promoting further search of scientific topics (weighted average increase = 7.35%). Considering the challenges modern society faces, an informed and aware society is of the utmost importance (DeBoer, 2000; Hetland, 2011). The results here obtained support the high potential of the GAs as a scientific communication tool, to interest the public in science, as well as to lead that same audience to inform themselves, ultimately, contributing to a more informed and aware society.

While, in the present study, GAs generally led to higher scores of perceptions of the importance of the scientific topic (weighted average increase = 6.19%; microplastic articles not considered), this effect was not always significant. As described before, in the case of the microplastics article, the lack of significant difference might be attributed to the participant's pre-existing awareness of the topic, due to its high relevance in the context of modern society. Thus, we might consider that the GAs are particularly impactful for less familiar topics, which is good in the realm of science communication because it opens new opportunities to communicate topics that might not be at first glance the more obvious to communicate to a non-expert audience. Nevertheless, the general decrease of the GA impact in the seahorse analysis when compared to the average increase (%) of the *Anisakis* and microplastics articles, might suggest that the impact of the GA is at its maximum when the audience is not very familiar with the scientific topic, but the topic still impacts that same audience directly. This is because the seahorse article did not directly impact any fundamental area of the public life (as the other two did) which might be a justification for the general smaller impact of the GA in this case. Further research is necessary regarding the impact of the GA depending on the scientific content they transmit.

One of the most significant findings was the potential increased agreement to read the complete article (weighted average increase = 9.65%) when participants were presented with GAs, as the science communication goal is not only to inform but also to engage the audience deeply (Jucan & Jucan, 2014). The GA made the full article seem more approachable and worth the time investment necessary, compared to the TA. This finding underscores the potential of GAs to act as a bridge between science and the public, drawing readers from a superficial understanding to a deeper engagement with the scientific content. Additionally, these results might reflect a positive advantage not only on science communication but on science dissemination as well. If the readers are more willing to read the scientific article, and if they do so, this will translate into better impact metrics of the scientific article, making the article more relevant in the academic field, and ultimately reinforcing the strength of the article within the scientific community, as well as the relevance of the author (Bartling, 2014).

In the digital age, tools that effectively engage society in digital platforms, such as social media, are essential (Hunter, 2020). Thus, the significant increase in the likelihood of interaction with the abstract on social media with the GAs (weighted average increase = 13.86%) reveals to be a huge advantage as a scientific communication tool. The shareability of visually appealing GAs can lead to wider dissemination and greater public engagement with scientific topics. Despite that, it is important to note the ambiguous nature of the term visually appealing, since it is dependent on each person's opinion. This represents the need to define standard and universal guidelines concerning the design of each type of GA (Ibrahim, 2022; Lee & Yoo, 2023), particularly in the case of GAIs, where the range of design options is limitless due to its illustrated nature.

Interestingly, while GAs excelled in engaging the audience and boosting interest, they did not improve comprehension over TAs. Instead, the GAs only did not compromise the understanding, maintaining the level of understanding between GAs and TAs. Nevertheless, it is worth noting that further research should evaluate these questions, to understand if the results remain consistent when different types of comprehensive questions are made. A follow-up study might be relevant in this context, to understand if the comprehension remains the same for both of the elements in two moments separated in time. This finding indicates that while GAs are effective in capturing attention and fostering initial engagement, TAs remain essential for conveying detailed and complex information. This supports the complementary role of GAs and TAs in science communication.

4.3. Interest influence on key variables

In the correlation analysis section, we focussed on describing relationships between different variables. Understanding these relations can help uncover how different aspects of GAs are associated and how these influence the effectiveness of the format as a science communication tool. To achieve this, we employed Spearman's rank correlation coefficient. The correlations were performed between all the GA variables for each article separately. From these, the most relevant ones are the consistent influence of the interest level in every other variable (interest/importance; interest/interest to know more; interest/agreement; interest/probability) and the significant association between the interest to know more and the agreement to read the complete article. The remaining correlations were found not significant for all of the three articles or just significant in one article, which in this context was not considered to be relevant to discuss. Table 37 illustrates the significant results obtained. The correlation between interest and perceived importance is significant for both the microplastics and the seahorse article. This means that the participants who find the topic interesting are also likely to perceive it as important. This is vital for science communication as it shows that engaging content can enhance the perceived relevance of scientific topics, potentially influencing public opinion and support for scientific research. In the case of the *Anisakis* article, the correlation is not statistically significant. This might be due to the prior knowledge of the participants. Regarding the correlations between interest and interest to know more, the associations are strong across all articles, indicating that when participants are interested in the topic, they also have a strong desire to learn more about the topic. This reinforces the importance of making scientific topics engaging and accessible to stimulate curiosity and further search. Similarly, the correlation is significant for all the articles between interest and agreement to read the complete article. In science communication, this might be essential as it suggests that GAs can lead to deeper engagement with the scientific content.

Table 37: Interest influence on key variables.

	Article	Test Statistic	p-value
Interest (topic)/ Importance	Anisakis	0.250	0.870
	Microplastics	0.457	<0.001
	Seahorse	0.468	<0,001
Interest (topic)/ Interest (know +)	Anisakis	0.695	<0.001
	Microplastics	0.670	<0.001
	Seahorse	0.759	<0.001
Interest (topic)/ Agreement	Anisakis	0.287	<0.001
	Microplastics	0.553	<0.001
	Seahorse	0.534	<0.001
Interest (topic)/ Probability	Anisakis	0.483	<0.001
	Microplastics	0.374	<0.001
	Seahorse	0.532	<0.001
Interest know(+)/ importance	Anisakis	0.475	<0.001
	Microplastics	0.492	<0.001
	Seahorse	0.701	<0.001

Finally, high interest is significantly associated with a high probability of social media interaction for all three articles. This suggests that participants who find the topic interesting are more likely to share or engage with the content on social media, highlighting the role of engaging content in promoting science communication through social platforms. Every variable presented a correlation with the level of interest in the topic. This reflects that engaging scientific communication tools, which boost the interest of the participants, is the basis to boost every other aspect relevant to effectively communicate complex scientific information.

Interestingly, participants who showed a high level of interest in knowing more about the topic consistently (across the three articles) reported a higher agreement level about reading the complete article. Since the complete article is an opportunity to know more about the topic, this association was expected. Nevertheless, this correlation highlights a significant opportunity to boost the accessibility and impact of scientific articles. Nowadays, when the public intends to know more about a topic, they often resort to internet searches and similar platforms (Vicente-Saez & Martinez-Fuentes, 2018). If scientific articles were made easily accessible to the public, GAs could create more chances for the public to turn to these articles rather than the internet alone. The importance of open science is herein highlighted to allow scientific communication tools to work at their maximum (Bartling, 2014).

4.4. Experts perspectives

The expert section of this study aimed to gather insights from scientific researchers regarding their perspectives and evaluations of GAs. This section focuses on understanding how experts, perceive the effectiveness, clarity and overall utility of these formats. The feedback from experts is essential as it provides a professional perspective on the potential advantages and limitations of GAs and TAs in disseminating scientific information.

Of the 23 scientific researchers who participated in this study, 22 progressed to the experts section of the survey. From that 22, 10 answered the questions about the *Anisakis* article, 4 about the microplastics article and 8 about the seahorse article. The experts were asked if they considered that the GA presented to them represented the corresponding TA well. Table 38 illustrates descriptive the results.

Table 38: Descriptive results GA representation - experts.

		1	2	3	4	5	
GA represent well the TA	%	4.5%	18.2%	9.1%	40.5%	27.3%	100
	$\bar{x}$	3.68					

In both tables the frequency (%) is calculated based on N=85 and N=83, respectively. The mean ($\bar{x}$) represents the mean value of the options selected (1 to 5). The question asked: Please indicate on the following scale your level of agreement with the following statement: "I consider that the GAs adequately represent the textual abstract.". Option 1 is "Totally disagree"; 2 is "Partially disagree"; 3 is "Neither agree nor disagree"; 4 is "Partially agree", 5 is "Totally agree".

The majority of the researchers considered the GA element to be representative of the corresponding TA (40.5% "partially agree" and 27.3% "totally agree". A smaller, yet notable proportion of the experts (22.7%) disagree or strongly disagree, suggesting that some experts have reservations about the fidelity of the GAs. These highlight once more the need to provide standard guidelines for GA design, even knowing that a scientific communication tool will never appeal to all.

Secondly, the researchers were asked about the likelihood of including a GA in a future article. The results are represented in Table 39.

Table 39: Descriptives results inclusion in future articles - experts.

		1	2	3	4	5	
GA inclusion in future articles	%	4.5%	18.2%	18,2%	31.8%	27.3%	100
	$\bar{x}$	3.59					

In both tables the frequency (%) is calculated based on N=85 and N=83, respectively. The mean ($\bar{x}$) represents the mean value of the options selected (1 to 5). The question asked: Indicate on the following scale the probability of including a graphical abstract in one of your future scientific articles". Option 1 is "Impossible"; 2 is "Unlikely"; 3 is "Likely"; 4 is "Very likely", 5 is "Certain".

The investigators present in this study seemed to be very receptive to including GAs in their future articles, with almost 60% reporting it to be very likely or certain. Nevertheless, 22.7% of the researchers do not intend to do it, with some saying it is impossible. To understand why these researchers do not intend to include GAs in their future research, and to have a general perspective of the limitations of the GAs according to them, the experts were given the opportunity to write about the disadvantages they found in GA implementation. Ten of the twenty-two participants answered with their perspectives. As this was an open-ended question, it was necessary to categorize the answers. To further explore the answers provided by the researchers refer to Attachment [6]. The limitations provided by the researchers comprise the following categories:

- Time investment and extra effort
- Require graphic design skills
- Incompatibility with some research topics (complexity)
- Professionalism concerns

The experts addressed some practical barriers, such as the need for graphical design skills and the suitability of GAs for different types of research. Additionally, the extra time and effort involved in the development of the GA, represent a relevant limitation to GA implementation. Overall, the concerns identified are the ones previously referred to by the literature, reinforming these limitations and the need for a solution (Lee & Yoo, 2023). Having a specialized professional, developing the GAs could be a solution to the practical limitations, such as time, effort, and graphic design skills. However, this has associated costs. Finally, it is important to note that some researchers fear that the GAs might undermine the perceived professionalism of scientific publications. These experts feel that the GAs could be seen as less rigorous or too simplistic. Additionally, some experts feel that the academic community might not welcome this element, thus fear being seen as lesser professionals due to the use of GAs. Likewise, it is necessary to address this within the academic community to make it clear that the advantages of the GAs surpass its limitations.

Chapter 5: Conclusion and future work

5. Summary

Within the present dissertation, a comparative study between GAs and TAs was implemented, in an attempt to contribute to reasoning the implementation of GAs as a scientific communication tool. In this chapter, we thereby aim to present the main conclusions inferred from our work. Lastly, given that the present study is just a first step in the topic, future work that needs to be carried out in light of the derived conclusions is explored.

5.1. Conclusion

As the science communication field grows and society evolves, the techniques and tools applied in the field change and improve accordingly. Nowadays, society demands for quick information and continuous stimuli, but the abundance of available information does not always reflect quality and factual accuracy. Scientists have relied on scientific publication ever since science works as we know it today, yet it remains challenging for scientific articles to reach beyond the world of the scientific community. Consequently, the general public does not easily benefit from the reliable information that scientific articles typically provide.

Graphical abstracts offer an innovative way of transforming scientific articles into effective scientific communication tools, especially the graphical abstract in infographic style. Despite its potential, graphical abstracts lack sufficient evidence to prove their effectiveness. Given the limited research conducted to date, this study intended to determine whether there were significant reasons to consider implementing graphical abstracts both as the main element of the scientific publication and to justify the cost for publishers to hire professional graphic designers, as creating graphical abstracts requires detailed technical skills not typically possessed by researchers.

Our results, across the three scientific articles analysed, strongly support the implementation of GAs, showing high increases in interest, interaction and further exploration of the scientific publication without compromising the detailed understanding of the matter that the primary source of information, the textual abstract, provides. The study also revealed that the impact of GAs might vary depending on the scientific topic. GAs appear to have maximum impact when the topic impacts society, but at the same time are not well-known or generally discussed, as the public’s prior knowledge influences the GA’s effectiveness. Additionally, the results show that GA impacts participants of all genders and age groups similarly, which is very important in the broad field of science communication, as it ensures effectiveness across a large proportion of the population, ultimately expanding science. Expert feedback corroborated these findings, with a majority recognizing the effectiveness of GAS in presenting scientific content. However, there are some concerns highlighted by them that need work and further investigation to solve.

Ultimately, the study highlights the significant potential of GAs as a scientific communication tool, working both independently and as a complementary tool. On its own, GAs raise awareness about the topic, attracting those who might otherwise be disinterested in traditional means of science communication. The dual approach of utilizing both GAs and TAs can attend to a wider audience spectrum, from casual readers to those seeking detailed scientific information. In this way, the GA works as an attention-grabber, directing interested readers to the TA and the full article.

Nevertheless, there is a long path to reach full implementation of GAs as a scientific communication tool, thus making it necessary to continuously work on the topic, additional investigation and intermediate solutions that can satisfy both the audience and the scientific community.

5.2. Future work

Firstly, due to the limited literature on this topic, it is essential to conduct similar research with different samples and contexts to validate and expand upon these findings. Secondly, establishing direct and “universal” guidelines for GA development is urgent to ensure their quality and reliability.

For broader implementation, further large-scale research is recommended. Additionally, research that specifically explores the influence of the diverse scientific fields on the effectiveness of GAs is necessary. Regarding comprehension, it would be beneficial to understand the role of GAs in retained understanding by conducting follow-up studies, where the participants received the same information either in GA or TA format.

As the full implementation of GAs might be a lengthy process, the development of “tool kits” could serve as an effective intermediate solution. These tool kits would not require excessive time from the researchers nor substantial investment from publishers. The tool kit could consist of several templates from which the researchers could choose, allowing them to better adapt to their needs. These templates could be accompanied by a diverse set of science-related images that the researchers could apply to the template based on their scientific field and research topic. The formulation of these elements would be straightforward, enabling researchers to create GAs themselves using familiar platforms such as Microsoft PowerPoint. This approach could serve as a good initial compromise to balance effectiveness, time and investment.

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Attachment [1] – Support of the ethics committee

U.PORTO
FACULDADE DE CIÊNCIAS
UNIVERSIDADE DO PORTO

Comissão de Ética

Parecer

Ref.: Proc. CE2024/p151

Relativamente ao pedido de parecer requerido por Mariana Sofia Subtil Campos no âmbito do projeto de investigação intitulado "Evaluation of the impact of graphical abstracts on science communication to non-expert audiences", a Comissão de Ética nada tem a opor à realização desse projeto, uma vez que estão garantidos o anonimato para o exterior, a confidencialidade no tratamento dos dados recolhidos e o consentimento informado dos participantes no referido projeto.

Faculdade de Ciências da Universidade do Porto, 3 de maio de 2024

O Presidente da Comissão de Ética

Assinado por: **João José de Faria Graça Afonso Lima**
Num. de Identificação: 07103810
Data: 2024.05.03 13:57:57+01'00'

Attachment [2] - Survey

Types of abstracts in scientific articles and its disclosure to non-expert public

Welcome!

First of all, we would like to thank you for participating in this study. The results obtained from this online survey will be used as part of a master's thesis at the Faculty of Sciences of the University of Porto, making your contribution essential. We assure you that the results of this study will be used solely for the purpose of this research, and it will be anonymous and confidential. Completing this questionnaire signifies your informed consent for the use of your responses in the study and any resulting publications. We estimate that it will take about 8 minutes to complete this survey, and we appreciate the time you dedicate to it.

Graphical abstracts are visual representations of the main concepts and findings of a scientific article, contrasting with the usual written abstracts - textual abstracts. Our goal is to explore the potential of graphical abstracts as an effective tool to enhance the level of interest and understanding of science among a non-specialist audience.

This questionnaire is structured into 5 sections, and it is not possible to go back once you have responded to each of them. At the beginning of each section, there are instructions for completing it. If you have any questions or would like more information, please do not hesitate to contact us at: up202204658@up.pt.

Thank you for contributing to scientific research.

Select “Next Page” to begin!

Section 1: Answer the following questions by selecting the option that best suits you.

<u>Question 1</u>

Please indicate your gender:

- ○ Male (1)

- Female (2)
- Non-binary (3)
- Rather not answer (4)

Question 2

Please indicate your gender:

- 18-24 years (1)
- 25-34 years (2)
- 35-44 years (3)
- 45-54 years (4)
- 55-64 years (5)
- 65 or more years (6)

Question 3

Please indicate your nationality: ________________________

Question 4

Please indicate your level of education:

- Basic school (1)
- High school (2)
- Bachelor's degree (3)
- Master's degree (4)
- PhD degree (5)

Question 5

Please indicate your profession:

- ○ Students (1)
- ○ Research scientist (2)
- ○ Other (3) ________________________

Section 2: The following questions relate to your interaction with scientific articles. On the provided scales select the option that best fits your reality/opinion.

Question 1

Please indicate on the following scale the frequency with which you read scientific articles:

- ○ Never (1)
- ○ Rarely (2)
- ○ Occasionally (3)
- ○ Frequently (4)
- ○ Very frequently (5)

Question 2

(Present this question: If "Indicate on the following scale the frequency with which you read scientific articles" = 1 – "Never")
Please indicate why you read scientific articles:

- ○ Academic reasons (1)
- ○ Professional reasons (2)
- ○ Personal interest (3)
- ○ Other (4) _______________________

Question 3

Please indicate on the following scale your degree of agreement with the following statement: "Scientific articles should be targeted only at professionals specialized in the corresponding knowledge area.":

- ○ Totally disagree (1)
- ○ Partially disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Partially agree (4)
- ○ Totally agree (5)

Question 4

Please indicate on the following scale your opinion on the importance of communicating science to the general public:

- ○ Not important at all (1)
- ○ Of little importance (2)
- ○ Moderately important (3)
- ○ Important (4)
- ○ Very important (5)

Assignment question

In order to proceed, please choose one of the following numbers:

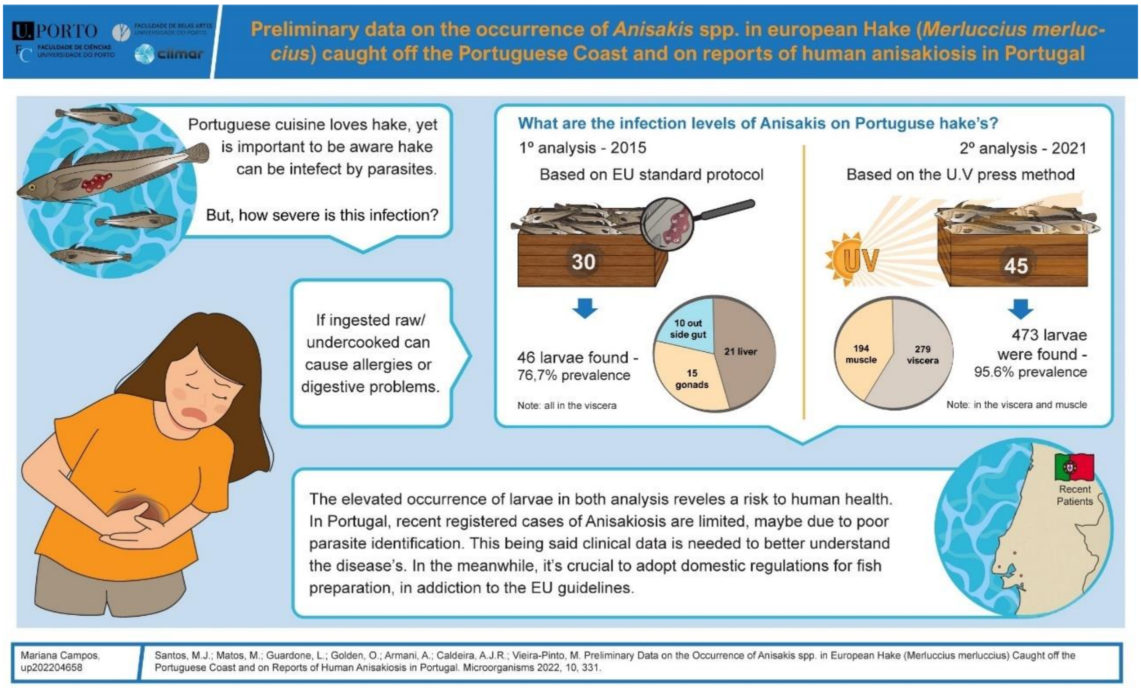
- ○ 1
- ○ 2
- ○ 3

(*Anisakis* branch)

This section is divided into 2 subsections and is based on the scientific article: " Preliminary data on the occurrence of *Anisakis* Spp. in European Hake Caught off the Portuguese Coast and on reports of human Anisakiasis in Portugal". In one of the subsections, we ask you to answer 8

questions based on the provided figure - graphical abstract of this scientific article, and in the other subsection we ask you to answer those same 8 questions considering the textual abstract of the article. Although the questions are the same in both subsections, it is not mandatory for the answers to be the same. The order in which the subsections appear is random, and we remind you that is not possible to go back between them.

GA section: Answer the following questions considering the figure presented at the beginning of the page - graphical abstract.



Question 1

Write the word that best describes your first impression when viewing this figure: ________________________________

Question 2

Indicate on the following scale your level of interest regarding the topic described in this figure:

- ○ Not interested at all (1)
- ○ Not very interested (2)
- ○ Indifferent (3)
- ○ Interested (4)
- ○ Very interested (5)

Question 3

Select the option that describes the main objective of this study:

- ○ Determine the infection levels (by *Anisakis* spp.) in hake in Portugal. (1)
- ○ Define the locations with the highest distribution of parasites (*Anisakis* spp.) in hake in Portugal. (2)
- ○ Promote the creation of national legislation on food preparation, particularly hake, in Portugal. (3)
- ○ Determine the infection levels in hake and the occurrence of anisakiasis in Portugal. (4)

Question 4

Select the option that describes the main discovery of this study:

- ○ High prevalence of parasites in Portuguese hake. (1)
- ○ Consumption of undercooked or raw hake may harm the consumer health. (2)
- ○ There is a wealth of clinical data on the disease caused by the mentioned infection. (3)
- ○ Parasite larvae primarily settle in the muscles of hake. (4)

Question 5

Indicate on the following scale the level of importance you attribute to the topic mentioned in this figure for the food safety and public health of Portuguese society:

- ○ Not important at all (1)
- ○ Of little importance (2)
- ○ Moderately important (3)
- ○ Important (4)
- ○ Very important (5)

Question 6

Indicate on the following scale your level of interest in learning more about the topic addressed in this figure:

- ○ Not interested at all (1)
- ○ Not very interested (2)
- ○ Indifferent (3)
- ○ Interested (4)
- ○ Very interested (5)

Question 7

Indicate on the following scale your level of agreement with the following statement: "If made available for free, I would read the full scientific article associated with this figure.":

- ○ Totally disagree (1)
- ○ Partially disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Partially agree (4)
- ○ Totally agree (5)

Question 8

Indicate on the following scale the probability of interacting with this element if you encountered it on a social media platform (*Twitter, Instagram, etc.*):

○ Impossible (1)
○ Unlikely (2)
○ Likely (3)
○ Very likely (4)
○ Certain (5)

TA section: Answer the following questions considering the text presented at the beginning of the page - textual abstract.

Title: Preliminary Data on the Occurrence of Anisakis spp. in European Hake (Merluccius merluccius) Caught off the Portuguese Coast and on Reports of Human Anisakiosis in Portugal

Parasitic nematodes of the genus Anisakis are among the most important biological hazards associated with seafood. A survey of Anisakis spp. in European hake (Merluccius merluccius) was undertaken as this species is a staple of the Portuguese diet. Moreover, a literature review of cases of anisakiosis reported from Portugal, a country with one of the highest levels of fish consumption in the world, was also carried out. Seventy-five European hake caught in the Atlantic Ocean off the northern coast of Portugal were analyzed to determine the infection levels and site distribution of Anisakis spp. Isolated nematode larvae were identified to species level by molecular analysis. Two sets of samples were collected. Firstly, a total of 46 Anisakis spp. L3 larvae were collected with a prevalence of 76.7% (95% CI 61.5–91.8%) and intensity (mean SD, range) of 2.0 1.2 (1–5). Most larvae were found on the liver (45.7%) and on the gonads (32.6%), but none in the muscle. The molecular analysis showed the presence of both A. simplex s.s. (70%) and A. pegreffii (30%). For the second sample, analyzed using the UV-Press method, a total of 473 Anisakis spp. were found, with a prevalence of 95.6% (95% CI 89.5–100.0%), intensity (mean SD, range) of 11.3 9.7 (1–41), density of 0.05 0.04 (0–0.16) worms/muscle weight in g, and density of 0.54 0.50 (0–2.53) worms/viscera weight in g. Surprisingly, only three very recent cases of human anisakiosis in Portugal have been reported in the literature. Data from this study contribute towards an updating of the existing epidemiological picture in an area characterized by very high seafood consumption and changing eating habits.

Question 1

Write the word that best describes your first impression when viewing this figure: ________________________________

Question 2

Indicate on the following scale your level of interest regarding the topic described in this figure:

- ○ Not interested at all (1)
- ○ Not very interested (2)
- ○ Indifferent (3)
- ○ Interested (4)
- ○ Very interested (5)

<u>Question 3</u>

Select the option that describes the main objective of this study:

- ○ Determine the infection levels (by *Anisakis* spp.) in hake in Portugal. (1)
- ○ Define the locations with the highest distribution of parasites (*Anisakis* spp.) in hake in Portugal. (2)
- ○ Promote the creation of national legislation on food preparation, particularly hake, in Portugal. (3)
- ○ Determine the infection levels in hake and the occurrence of anisakiasis in Portugal. (4)

<u>Question 4</u>

Select the option that describes the main discovery of this study:

- ○ High prevalence of parasites in Portuguese hake. (1)
- ○ Consumption of undercooked or raw hake may harm the consumer health. (2)
- ○ There is a wealth of clinical data on the disease caused by the mentioned infection. (3)
- ○ Parasite larvae primarily settle in the muscles of hake. (4)

<u>Question 5</u>

Indicate on the following scale the level of importance you attribute to the topic mentioned in this figure for the food safety and public health of Portuguese society:

- ○ Not important at all (1)

- Of little importance (2)
- Moderately important (3)
- Important (4)
- Very important (5)

Question 6

Indicate on the following scale your level of interest in learning more about the topic addressed in this figure:

- Not interested at all (1)
- Not very interested (2)
- Indifferent (3)
- Interested (4)
- Very interested (5)

Question 7

Indicate on the following scale your level of agreement with the following statement: "If made available for free, I would read the full scientific article associated with this figure.":

- Totally disagree (1)
- Partially disagree (2)
- Neither agree nor disagree (3)
- Partially agree (4)
- Totally agree (5)

Question 8

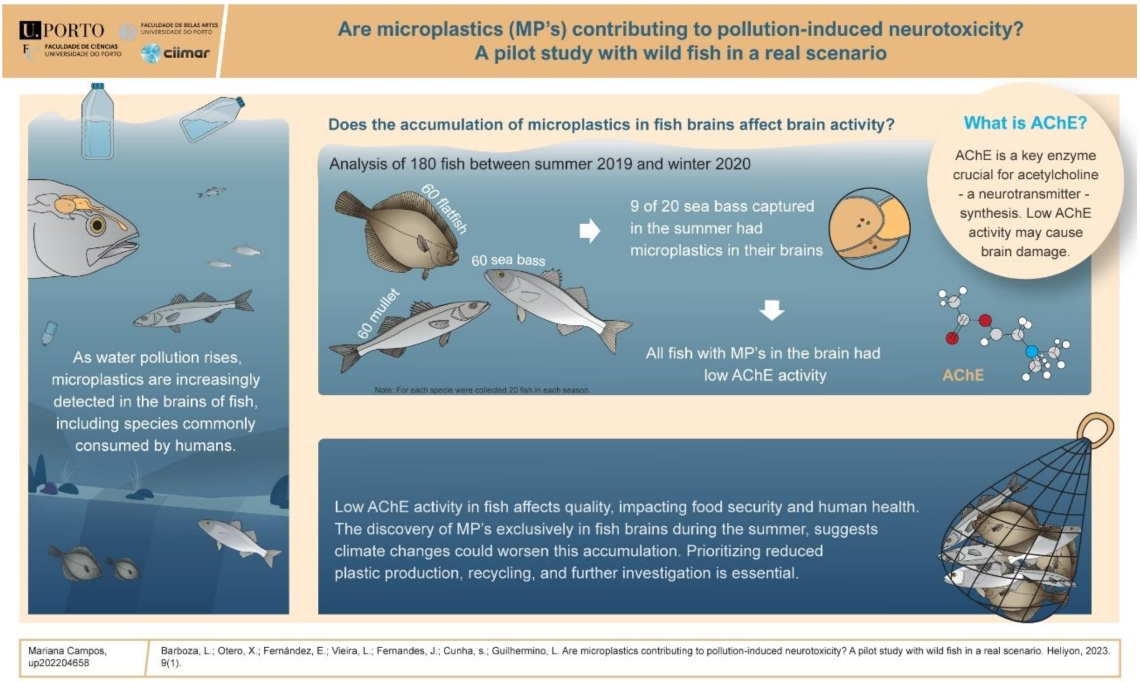
Indicate on the following scale the probability of interacting with this element if you encountered it on a social media platform (*Twitter, Instagram, etc.*):

- ○ Impossible (1)
- ○ Unlikely (2)
- ○ Likely (3)
- ○ Very likely (4)
- ○ Certain (5)

(Microplastics branch)

This section is divided into 2 subsections and is based on the scientific article: "Are microplastics contributing to pollution-induced neurotoxicity? A pilot study with wild fish in a real scenario". In one of the subsections, we ask you to answer 8 questions based on the provided figure - graphical abstract of this scientific article, and in the other subsection we ask you to answer those same 8 questions considering the textual abstract of the article. Although the questions are the same in both subsections, it is not mandatory for the answers to be the same. The order in which the subsections appear is random, and we remind you that is not possible to go back between them.

GA section: Answer the following questions considering the figure presented at the beginning of the page - graphical abstract.



Question 1

Write the word that best describes your first impression when viewing this figure: ________________________________

Question 2

Indicate on the following scale your level of interest regarding the topic described in this figure:

- ○ Not interested at all (1)
- ○ Not very interested (2)
- ○ Indifferent (3)
- ○ Interested (4)
- ○ Very interested (5)

Question 3

Select the option that describes the main objective of this study:

- ○ Understanding how the potential presence of microplastics in the brains of wild fish relates to the activity of the enzyme AChE. (1)
- ○ Understanding the functioning of the AChE enzyme. (2)
- ○ Identifying microplastics in the brains of aquaculture fish and the activity of the AChE enzyme. (3)
- ○ Raising awareness about the impact of climate change on human health. (4)

Question 4

Select the option that describes the main discovery of this study:

- ○ Only microplastics are found in the brains of seabass collected in the summer. (1)
- ○ All fish with microplastics in their brains exhibit low levels of AChE activity when compared to fish free of microplastics. (2)

- ○ Confirmation, in a real-world scenario, of the passage of microplastics through the blood-brain barrier, previously confirmed only in the laboratory. (3)
- ○ AChE is a key enzyme in the synthesis of acetylcholine, one of the main neurotransmitters involved in brain activity. (4)

Question 5

Indicate on the following scale the level of importance you attribute to the topic mentioned in this figure for the food safety and public health of Portuguese society:

- ○ Not important at all (1)
- ○ Of little importance (2)
- ○ Moderately important (3)
- ○ Important (4)
- ○ Very important (5)

Question 6

Indicate on the following scale your level of interest in learning more about the topic addressed in this figure:

- ○ Not interested at all (1)
- ○ Not very interested (2)
- ○ Indifferent (3)
- ○ Interested (4)
- ○ Very interested (5)

Question 7

Indicate on the following scale your level of agreement with the following statement: "If made available for free, I would read the full scientific article associated with this figure.":

- ○ Totally disagree (1)
- ○ Partially disagree (2)

- Neither agree nor disagree (3)
- Partially agree (4)
- Totally agree (5)

Question 8

Indicate on the following scale the probability of interacting with this element if you encountered it on a social media platform (*Twitter, Instagram, etc.*):

- Impossible (1)
- Unlikely (2)
- Likely (3)
- Very likely (4)
- Certain (5)

TA section: Answer the following questions considering the figure presented at the beginning of the page - graphical abstract.

Title: Are microplastics contributing to pollution-induced neurotoxicity? A pilot study with wild fish in a real scenario

Pollution-induced neurotoxicity is of high concern. This pilot study investigated the potential relationship between the presence of microplastics (MPs) in the brain of 180 wild fish (Dicentrarchus labrax, Platichthysflesus, Mugil cephalus) from a contaminated estuary and the activity of the acetylcholinesterase (AChE) enzyme. MPs were found in 9 samples (5% of the total), all of them from D. labrax collected in the summer, which represents 45% of the samples of this species collected in that season (20). Seventeen MPs were recovered from brain samples, with sizes ranging from 8 to 96 µm. Polyacrylamide, polyacrylic acid and one biopolymer (zein) were identified by Micro-Raman spectroscopy. Fish with MPs showed lower ($p \leq 0.05$) AChE activity than those where MPs were not found. These findings point to the contribution of MPs to the neurotoxicity induced by long-term exposure to pollution, stressing the need of further studies on the topic to increase 'One Health' protection.

Question 1

Write the word that best describes your first impression when viewing this figure: ______________________________

Question 2

Indicate on the following scale your level of interest regarding the topic described in this figure:

- ○ Not interested at all (1)
- ○ Not very interested (2)
- ○ Indifferent (3)
- ○ Interested (4)
- ○ Very interested (5)

Question 3

Select the option that describes the main objective of this study:

- ○ Understanding how the potential presence of microplastics in the brains of wild fish relates to the activity of the enzyme AChE. (1)
- ○ Understanding the functioning of the AChE enzyme. (2)
- ○ Identifying microplastics in the brains of aquaculture fish and the activity of the AChE enzyme. (3)
- ○ Raising awareness about the impact of climate change on human health. (4)

Question 4

Select the option that describes the main discovery of this study:

- ○ Only microplastics are found in the brains of seabass collected in the summer. (1)
- ○ All fish with microplastics in their brains exhibit low levels of AChE activity when compared to fish free of microplastics. (2)
- ○ Confirmation, in a real-world scenario, of the passage of microplastics through the blood-brain barrier, previously confirmed only in the laboratory. (3)
- ○ AChE is a key enzyme in the synthesis of acetylcholine, one of the main neurotransmitters involved in brain activity. (4)

Question 5

Indicate on the following scale the level of importance you attribute to the topic mentioned in this figure for the food safety and public health of Portuguese society:

- Not important at all (1)
- Of little importance (2)
- Moderately important (3)
- Important (4)
- Very important (5)

Question 6

Indicate on the following scale your level of interest in learning more about the topic addressed in this figure:

- Not interested at all (1)
- Not very interested (2)
- Indifferent (3)
- Interested (4)
- Very interested (5)

Question 7

Indicate on the following scale your level of agreement with the following statement: "If made available for free, I would read the full scientific article associated with this figure.":

- Totally disagree (1)
- Partially disagree (2)
- Neither agree nor disagree (3)
- Partially agree (4)
- Totally agree (5)

Question 8

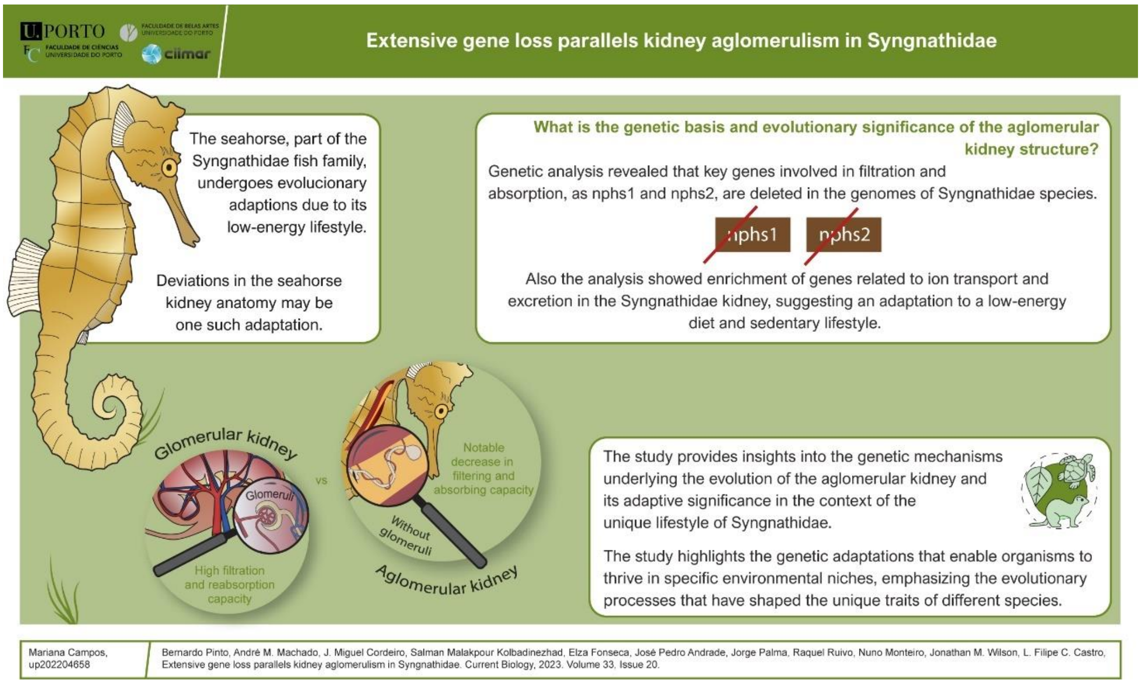
Indicate on the following scale the probability of interacting with this element if you encountered it on a social media platform (*Twitter, Instagram, etc.*):

- Impossible (1)
- Unlikely (2)
- Likely (3)
- Very likely (4)
- Certain (5)

(Seahorse branch)

This section is divided into 2 subsections and is based on the scientific article: "Extensive gene loss parallels kidney aglomerulism in Syngnathidae". In one of the subsections, we ask you to answer 8 questions based on the provided figure - graphical abstract of this scientific article, and in the other subsection we ask you to answer those same 8 questions considering the textual abstract of the article. Although the questions are the same in both subsections, it is not mandatory for the answers to be the same. The order in which the subsections appear is random, and we remind you that is not possible to go back between them.

GA section: Answer the following questions considering the figure presented at the beginning of the page - graphical abstract.



<u>Question 1</u>

Write the word that best describes your first impression when viewing this figure: ______________________________

<u>Question 2</u>

Indicate on the following scale your level of interest regarding the topic described in this figure:

- ○ Not interested at all (1)
- ○ Not very interested (2)
- ○ Indifferent (3)
- ○ Interested (4)
- ○ Very interested (5)

<u>Question 3</u>

Select the option that describes the main objective of this study:

○ Find evidence that the aglomerular kidney of the seahorse is the result of an evolutionary energy-saving mechanism. (1)

- Conduct a molecular and genetic analysis of the seahorse genome. (2)
- Highlight the importance of evolutionary adaptations for biodiversity. (3)
- Comparatively analyse the glomerular kidney and the aglomerular kidney. (4)

Question 4

Select the option that describes the main discovery of this study:

- The genes responsible for the filtration and absorption capacity of the kidney are not present in the analysed genomes. (1)
- Genomic analysis supports the proposal that the aglomerular kidney evolved as an energy-saving strategy. (2)
- Various gene loss processes occurred in the seahorse genome. (3)
- Organisms of this family (Syngnathidae) have low-energy lifestyle adaptations. (4)

Question 5

Indicate on the following scale the level of importance you attribute to the topic mentioned in this abstract to the conservation and preservation of biodiversity:

- Not important at all (1)
- Of little importance (2)
- Moderately important (3)
- Important (4)
- Very important (5)

Question 6

Indicate on the following scale your level of interest in learning more about the topic addressed in this figure:

- Not interested at all (1)
- Not very interested (2)
- Indifferent (3)
- Interested (4)

- ○ Very interested (5)

Question 7

Indicate on the following scale your level of agreement with the following statement: "If made available for free, I would read the full scientific article associated with this figure.":

- ○ Totally disagree (1)
- ○ Partially disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Partially agree (4)
- ○ Totally agree (5)

<u>Question 8</u>

Indicate on the following scale the probability of interacting with this element if you encountered it on a social media platform (*Twitter, Instagram, etc.*):

- ○ Impossible (1)
- ○ Unlikely (2)
- ○ Likely (3)
- ○ Very likely (4)
- ○ Certain (5)

TA section: Answer the following questions considering the figure presented at the beginning of the page - graphical abstract.

Title: Extensive gene loss parallels kidney aglomerulism in Syngnathidae

The eccentric seahorses, seadragons, pipehorses and pipefi shes (Syngnathidae) have an aglomerular kidney. Here, we show that nephron genes conserved in Bilateria are secondarily eroded/deleted in Syngnathidae genomes. A transcriptome enrichment analysis suggests the predominance of excretion processes in the Syngnathidae kidney. In a lineage where crypsis and idleness are tightly associated, we propose that aglomerulism evolved as an energy saving strategy.

<u>Question 1</u>

Write the word that best describes your first impression when viewing this figure: ________________________________

Question 2

Indicate on the following scale your level of interest regarding the topic described in this figure:

- ○ Not interested at all (1)
- ○ Not very interested (2)
- ○ Indifferent (3)
- ○ Interested (4)
- ○ Very interested (5)

Question 3

Select the option that describes the main objective of this study:

- ○ Find evidence that the aglomerular kidney of the seahorse is the result of an evolutionary energy-saving mechanism. (1)
- ○ Conduct a molecular and genetic analysis of the seahorse genome. (2)
- ○ Highlight the importance of evolutionary adaptations for biodiversity. (3)
- ○ Comparatively analyse the glomerular kidney and the aglomerular kidney. (4)

Question 4

Select the option that describes the main discovery of this study:

- ○ The genes responsible for the filtration and absorption capacity of the kidney are not present in the analysed genomes. (1)
- ○ Genomic analysis supports the proposal that the aglomerular kidney evolved as an energy-saving strategy. (2)
- ○ Various gene loss processes occurred in the seahorse genome. (3)
- ○ Organisms of this family (Syngnathidae) have low-energy lifestyle adaptations. (4)

Question 5

Indicate on the following scale the level of importance you attribute to the topic mentioned in this abstract to the conservation and preservation of biodiversity:

- ○ Not important at all (1)
- ○ Of little importance (2)
- ○ Moderately important (3)
- ○ Important (4)
- ○ Very important (5)

Question 6

Indicate on the following scale your level of interest in learning more about the topic addressed in this figure:

- ○ Not interested at all (1)
- ○ Not very interested (2)
- ○ Indifferent (3)
- ○ Interested (4)
- ○ Very interested (5)

Question 7

Indicate on the following scale your level of agreement with the following statement: "If made available for free, I would read the full scientific article associated with this figure.":

- ○ Totally disagree (1)
- ○ Partially disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Partially agree (4)
- ○ Totally agree (5)

Question 8

Indicate on the following scale the probability of interacting with this element if you encountered it on a social media platform (*Twitter, Instagram, etc.*):

- ○ Impossible (1)
- ○ Unlikely (2)
- ○ Likely (3)
- ○ Very likely (4)
- ○ Certain (5)

(Experts branch)

Question 1

(Present this question ➐ If “Indicate your profession” = Scientific researcher)
Please indicate on the following scale your level of agreement with the following statement: "I consider that the graphical abstracts adequately represent the textual abstract.".

- ○ Totally disagree (1)
- ○ Partially disagree (2)
- ○ Neither agree nor disagree (3)
- ○ Partially agree (4)
- ○ Totally agree (5)

Question 2

(Present this question ➐ If “Indicate your profession” = Scientific researcher)
Indicate on the following scale the probability of including a graphical abstract in one of your future scientific articles:

- ○ Impossible (1)
- ○ Unlikely (2)
- ○ Likely (3)
- ○ Very likely (4)
- ○ Certain (5)

Question 3

(Present this question ➐ If "Indicate your profession" = Scientific researcher) – optional
If you wish to share, please indicate the disadvantages you find in including graphical abstracts in scientific articles:

Final question

As a final consideration, select from the following list 3 options that you consider the main 3 consequences of science communication:

- ☐ Public access to scientific knowledge (1)
- ☐ Public engagement with science (2)
- ☐ Promoting informed decision making (3)
- ☐ Innovation and technological advancement (4)
- ☐ Demystification of science (5)
- ☐ Scientific awareness (6)
- ☐ Scientific sensationalism (7)
- ☐ Politicization of science (8)
- ☐ Distrust in science (9)
- ☐ Devaluation of science (10)

Attachment [3] – Answers first impression (*Anisakis*)

First impression GA

Categories	Answers
	166
Positive	Clear; easy; enlightening; top; clarity; innovative; attractive; simplified; explanatory; appealing; intuitive; easy (than the TA); accessible; informative; structured; accessible; intuitive; enlightening; immediate understanding; simple.
Negative	Visual discomfort; inconsequential; unappealing.
Neutral	Direct; information; succinct; different.
Feelings on the topic (+/-)	Curiosity; interesting; interesting; astonishment; concern; interesting; perplexed; curiosity, confusion, don't know how to answer; confusion but clear than the textual abstract.
Science Related	Health; contaminated food; seasickness; harm; food effects with contaminated hake; parasites; illness; hake; parasites; illness.
Total	214

First impression TA

Categories	Answers
	167
Positive	Completeness; thorough; informative.
Negative	Boring; boring; Difficult; disgust; inconsequential; complex; unclear; tedium; long; exhausting; extensive; dense (x6).
Neutral	Detailed; minimalist; data; classic; scientific; scientific; detailed; descriptive; descriptive; data.
Feelings on the topic (+/-)	Interest; interesting; interesting; afraid; intense and complex but elaborate; interesting, "UI", confusion (technical terms); I don't understand anything.
Science Related	Risks; contaminations; European hake; epidemiology; parasites; fish; larvae; parasites.
Total	214

Attachment [4] – Answers first impression (MP's)

First impression GA

Categories	Answers
	139
Positive	Informative; simplicity; informative; easy; explicit; appealing; interactive; appealing; illustrative; appealing; simple; informative; enlightening; appealing; colourful; attractive; intuitive; appealing; didactic; informative; informative; innovative; organization; informative; appealing; appealing; attractive; flashy.
Negative	Lots of information; negativity.
Neutral	Consequence; demonstration; current; organization; organization.
Feelings on the topic (+/-)	Interesting; afraid; devastating; interesting; sadness; interesting; horror; concern; curiosity (how we will be affected); interesting; interesting; interest; ache; interesting; tragedy; curiosity, confusion; confusion.
Science Related	Fish; cause-effect; pollution; pollution; degradation; ocean pollution; pollution; changes in fish; pollution; sea; pollution; pilot study with fishes in a real scenario; Açores; pollution; planet; fishes; fishes; biodiversity consequences; pollution; fishes; analyse; pollution; fish.
Total	214

First impression TA

Categories	Answers
	130
Positive	Knowledgeable; precision; informative, explanatory, simplicity; informative; succinct.
Negative	Complex; technical; boring; tedium; difficult; unclear; monotonous; dense; unappealing; dense; complex; disinteresting; dense; complex; complex; tedious; technical; difficult; tiring; dense; dense; unappealing.
Neutral	Classic; specific; information; small; information; detailed, text; current; scruffy; ok.
Feelings on the topic	Concern; concern; concern; interesting; horror; concern; interesting; concern; interesting; alert, tragedy.
Science Related	Microplastics; pollution; neurotoxicity; toxicity; pollution; neurotoxicity; pollution; pollution; pollution; pollution fishes; pollution; pilot study with fishes in a real scenario; investigation; pollution; microplastics; neurotoxicity, environment; negative impacts of microplastics; health; pollution; study, "One Health"; pollution; scientific.
Total	214

Attachment [5] – Answers first impression (Seahorse)

First impression GA

Categories	Answers
	131
Positive	Clarity; schematic; good; attractive; very good; very clear and explanatory; explicit; well organized; complete; creativity; clarity; informative; good; structured; appealing; catchy and simple to understand; objective; interactivity; didactic; attractive; accessible; didactic; appealing; appealing; appealing; catchy; clear; cute; flashy; comprehensive; appealing.
Negative	Uninteresting; excess; childish; low contrast.
Neutral	Blank spaces; poster; poster; pt; text; illustration; green.
Feelings on the topic (+/-)	Interesting; important; interesting; interesting; interesting; curiosity; interesting; interesting; interesting; interesting; curiosity, confusing; confuse; confuse; confuse; confuse.
Science Related	Seahorse; nature; evolution; seahorse; genetic; seahorse; seahorse; adaptation; kidney; genes; seahorse adaptation; seahorse; embryo; synthesis; seahorse; seahorse; seahorse; biology; Glomerular kidney; adaptation; biology; seahorse; animals; glomerular kidney; sea; seahorse.
Total	214

First impression TA

Categories	Answers
	133
Positive	Good; good; good; explanatory; good;
Negative	Disinformation; cryptography; monotonous; compact; complex; difficult; complex; difficult; complex; boring; complex; disinterest; terms technics and specifics; incomprehensible; complex; far-fetched; unknown words; difficult; boring; technical; complex; concise; complex; concise; monotonous; complex; unstructured.
Neutral	Specific; text; specific; intelligence; descriptive; direct; pt; synthetic; I don’t know; textual; abstract; synthetic; summary; Wikipedia; a lot of text; short.
Feelings on the topic (+/-)	Curiosity; interesting; curiosity; curiosity; attention, confusion, confusion, confusion (terms); confusion; confusion.

Science Related	Evolving; evolution; loss; adaptation; energy; fishes; environment; fishes; genes; aglomerular; kidney; seahorse; energy savings; evolution; evolution; niche; evolution; aglomerulismo.
Total	214

Attachment [6] – Answers disadvantages (Experts)

Experts perspectives		204
	Apesar de mais chamativos, são mais trabalhosos para os autores	
	Convém adequar o tipo de abstract ao tipo de público que lerá o artigo. No caso do graphical abstract, talvez o excessivo uso de imagens que não acrescentam nada ao artigo faz com que não seja muito pertinente para o artigo científico e crie ruído visual e de informação.	
	falta de formação dos autores na parte gráfica leva a que não haja graphical abstracts visualmente apelativos em simultâneo com a transmissão eficiente da mensagem	
	Not every topic of research might be compatible with such elaborate graphical representations. But wherever it is suitable to include such graphical features, most certainly, it would save time for readers of both scientific and laymen origins to quickly grasp the idea whereby piques more interest in actually reading the context and methodology or the research outcomes. I certainly am inspired through this idea for my future research work to include similar modality in abstracts.	
	O investimento de tempo na sua produção e a necessidade de possuir conhecimentos e competências ao nível das TIC (ou contratar alguém que às detenha) para a sua produção	
	Pelo exemplo, o graphical abstract pareceu um pouco "infantil" (em termos de imagem), o que para mim enquanto investigadora que lê frequentemente artigos poderia ter sido motivo (caso estivesse a investigar sobre este tema) para possivelmente não ter em conta o artigo na minha leitura. Sou a favor de graphical abstracts, mas penso que se deve ter em conta o tipo de gráficos utilizados de modo que o artigo não perca o cariz profissional que deve ter.	
	Por vezes se o trabalho tiver elevada complexidade é difícil de desenhar algo que o represente.	
	Relutância do meio académico	
	Scientists are not designers; takes a long time; also, the seahorse graphical abstract looks more like a slideshow of the abstract with extra text and childish drawings, instead of an actual visual representation of findings.	
	Trabalho extra que requer algum conhecimento gráfico	
	Total	214