# Deliverable 5.1

## Literature review about the science-journalism relationship

## Version 1.4

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## QUALITY ASSURANCE

To ensure the quality and correctness of this deliverable, we arranged an internal review and validation process. The deliverable was drafted by the work package leader (University of Twente). All partners contributed and reviewed the overall draft. Finally, the final version was submitted to the project coordinator for a final review and validation.

### STATEMENT OF ORIGINALITY AND DISCLAIMER

This deliverable contains original, unpublished work except where clearly indicated otherwise. It builds upon the experience of the team and related work published on this topic. Acknowledgement of previously published material and others' work has been made through appropriate citation, quotation, or both.

The views and opinions expressed in this publication are the authors' sole responsibility and do not necessarily reflect the views of the European Commission and the Research Executive Agency (REA), that are not responsible for any use that may be made of the information here contained.

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**ENJOI - ENgagement and JOurnalism Innovation for Outstanding Open Science Communication**
This project received funding from the European Union's Horizon 2020 Research and Innovation program under Grant Agreement n°101006407
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## SUMMARY

ENJOI aims to improve science communication by making it more consistently reliable, truthful, open and engaging. This report describes literature review results to develop a robust base for a series of studies within the ENJOI project that explore the science-media relationship. The literature review focuses on the quality and effectiveness of interactions between scientists and media to identify challenges and changes in the science-media relationship. It addresses how collaborations between scientists and media producers can improve accuracy in science communication and how these interactions can be fostered and improved.

This literature review includes 20 scientific articles and book chapters about science-media interactions published between 2001 and 2021 found in a first round of reviews. A second round of reviews was conducted in October 2022 which added another 17 articles to the sample. The samples were analysed using a review form that focused on: the roles of scientists and journalists; their reasons to interact with each other; and changes and challenges in these interactions. The results show that the process of medialisation of science and changes in the media landscape have influenced science-media interactions in positive and negative ways. Scientists and journalists are usually relatively positive about their interactions and believe that science communication is beneficial and important. The COVID-19 pandemic influenced interactions between journalists and experts with researchers being more available for journalists and at the same time journalists having to work under more pressure, in at least, some countries.

The main challenges in science-media interactions include a lack of skills, training, time and resources of both parties, and perceived problems with the accuracy of news reports about science. Proposed solutions include improving mutual understanding between scientists and journalists, creating networks for ongoing collaboration and providing training and support for scientists and journalists to communicate about science effectively.

This report is a living document to keep up with ongoing changes in the




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science-media relationship and with new developments related to the COVID-19 pandemic. We will continue to add literature about science-media interactions to this review throughout the ENJOI project in a next step in 2023 and focusing on published studies in the languages Italian, Portuguese and Spain. In this way, we can provide accurate and up-to-date information for the studies about the science-media relationship.

# PROJECT OVERVIEW

ENJOI (ENgagement and JOurnalism Innovation for Outstanding Open Science Communication) will explore and test engagement as a key asset of innovation in science communication distributed via media platforms, with a strong focus on journalism.

Through a combination of methodologies and in collaboration with producers, target users and stakeholders of science communication, ENJOI will co-create and select a set of standards, principles and indicators (SPIs) condensed to a Manifesto for an Outstanding Open Science Communication. ENJOI will deploy a series of actions via Engagement Workshops, Labs, field and participatory research, evaluation and testing phases.

It will also build an Observatory as its landmark product to make all results and outputs available to foster capacity building and collaboration of all actors in the field. ENJOI will work in four countries: Belgium, Italy, Portugal and Spain, taking into account different cultural contexts.

ENJOI's ultimate goal is that of improving science communication by making it more consistently reliable, truthful, open and engaging. Contextually, ENJOI will contribute to the active development of critical thinking, digital awareness and media literacy of all actors involved in the process.

# 1. INTRODUCTION

This report provides an overview of scientific literature about the science-media relationship. This literature review aims to develop a robust base for the studies exploring the science-media relationship within the ENJOI project. It will focus on the quality and effectiveness of interactions between scientists and media, specifically with journalists (for both traditional and social media) to identify challenges and changes in the science-media relationship.

These changes in the science-media relationship are happening quickly. During the past few decades, societies, and especially media-landscapes, have gone through far-reaching changes due to the development of internet and social media technologies (Dunwoody, 2014). New reflections on how these developments affect the science-media relationship are regularly published, particularly concerning disinformation, misinformation, and information overload. The rapid publication of new insights about the science-media relationship has increased even more since the outbreak of the COVID-19 pandemic. Due to the pandemic, science news became more salient and visible, drawing attention to the science-media relationship.

In order to keep up with these quick changes in the science-media relationship and new literature about this topic, this report will stay a living document. In the first round which was conducted in 2021, 20 articles were included and analysed. In the second round, in October 2022, another 17 articles were added to the corpus. Over time, new relevant literature will be added to the literature review for the duration of the ENJOI project. This will include a focused search for articles on the topic and published in the languages Italian, Portuguese and Spanish.

This literature review aims to answer the following research questions as formulated in the Grant Agreement (2020): *"How can active collaborations between scientists and media producers improve accuracy in science communication?"* and *"How can interactions between scientists and media producers be fostered and improved?"*.

The review will focus on how the science-media relationship is discussed in the

literature to answer these questions. First, reasons for scientists and journalists to engage in public communication about science will be discussed. Following this, descriptions of the roles of scientists and media producers in the science-media relationship will be drawn out. Finally, challenges and changes in the science-media relationship that have been identified in the literature and potential solutions to these issues will be discussed.

Chapter 2 describes the methodology for the literature review. The findings from the literature review are presented in Chapter 3 and discussed in Chapter 4. Finally, conclusions are drawn in Chapter 5.


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# 2. METHODOLOGY

This chapter describes the methods that were used in this literature review. It explains how the sample of articles and book chapters was selected and how the analysis was conducted.

## 2.1 Selection of the sample for the first round of analysis

An initial search for literature about interactions between scientists, media and the public was conducted in April 2021. We used the search terms "science-media relationship" and "science-society relationship" for this initial search. Both search terms were run in Scopus, Web of Science and Google Scholar databases. As a result, we found 89 unique articles in total: 48 related to the science-media relationship and 50 to the science-society relationship. Thereupon, we developed inclusion criteria to guide the process of selecting the most relevant articles for the analysis. General inclusion criteria were that literature should be written in English and published between 2001 and 2021 in scientific journals or books. In addition, the articles had to include information about the relationship between science and media.

After reading the titles and abstracts of the 89 preselected articles, 33 articles that seemed to fit the inclusion criteria were selected. After analysing this first sample, snowballing and reverse snowballing techniques were used to add other relevant articles and book chapters. Furthermore, we removed articles that did not include information about the science-media relationship. The total sample of the literature in the first round consisted of 20 articles and book chapters.

## 2.2 Selection of the articles for the second round

A second search for literature was conducted in October 2022. We updated and clarified the inclusion criteria to fulfil the research aim. Also for this second round literature needed to be published in scientific journals and books, in English, between 2001 and 2022. In addition, literature needed to include information about *direct interactions between scientists and media producers*. It led to the following search string:

"("science journalism" OR "science communication" OR "science-media") AND

(relationship OR collaboration OR interaction)”

Three steps were taken to find additional relevant studies. First, we selected and analysed additional papers based on a snowball search of references from the current corpus. Secondly, based on the updated and clarified selection criteria, we re-ran the search to check for additional studies and newer studies published in 2021 and 2022 with the search string as above. As a third step, we created a list with relevant journals which we double-checked for relevant articles although most of these journals were included in the initially searched databases. These three steps led to 86 articles from the snowball method and another 240 papers from the renewed database search. Doubles were removed. Accordingly, the abstracts were read and scanned and 30 articles were included for a full read. Finally, after the full read with help of the review form as described in 2.3, 17 new articles were added to the total corpus and the findings were added in the report.

Regarding the search criteria, these clarified more precisely when we would include or exclude studies in the selection, because the focus of the literature review was to better understand the relationships or interactions between researchers or scientists and journalists. This excludes, for example, how scientific information is framed in news sources. Hence, in the step with the selection based on title and abstract, some of the newly selected articles included studies that were not relevant and these were consequently excluded after a full read or analysis.

## 2.3 Materials

In order to analyse the literature, a review form was developed and used. This review form consisted of a table with topics, which the researchers could fill in for each article. The topics included general information about the article, the type and country of publication, the methods used, and what cases and perspectives the article or book chapter focused on. The form also included a section for comments on how the articles discussed the science-media relationship. For example, it included examples of reasons for interaction and roles of stakeholders to pay attention to. In addition, the form included sections to note what models, frameworks, concepts, processes or theories about science communication were mentioned and how these theoretical elements were discussed. Finally, the review form included the

possibility to add other comments about the article or book chapter.

The categories in the review form were informed by the research questions and suggestions from Petticrew and Roberts (2006) on conducting systematic reviews in social science. The examples in the review form were based on various other sources. For example, the reasons from Fiorino (1990) were used for the category about the interaction between scientists and media. The examples in the category about the roles of scientists were inspired by the roles of scientists who provide governance advice as described by Pielke (2007) and Spruijt et al. (2013). For the section about the roles of journalists, the categorisation of Fahy and Nisbet (2011) was used. Other categories in the review form used recurring topics from the titles, keywords and abstracts of the first selection of literature as examples.

A sample of ten articles from the first literature search was selected to test and improve the review form in an iterative process. New categories and examples were added based on relevant information that was found in the test sample. The whole process led to a final review form that can be found in *Appendix 1*.

# 3. RESULTS

This chapter describes the results of the literature review from the first round of analyses added with the findings from the second round. First, an overview of the literature included in the sample is provided. Next, results related to reasons for engagement are reported. The third section describes what roles of scientists and media producers were discussed in the literature. Finally, changes and challenges in the science-media relationship are identified and explained.

## 3.1 Overview of literature

Table 1 provides an overview of the literature included in the review in the first round. Each article or book chapter shows the authors, year and type of publication, the countries where the studies were conducted, the focus of the article, the included stakeholders, and the methods used. The focus includes cases or specific fields within science that the article or book chapter focused on. When science was discussed in general, the science communication topic that the article or book chapter focused on is mentioned instead. The category of included stakeholders mentions which stakeholders were included directly, for example, in the data collection process, or indirectly, for example, when authors reflected on their roles.

**Table 1**

*Overview of literature of the first round*

| Authors | Country | Type of publication | Focus | Included stakeholders | Methods |
|---|---|---|---|---|---|
| Allgaier et al., 2013 | USA, Germany | Journal article | neuroscience | scientists | interviews (n=30) |
| Appiah et al., 2020 | Ghana, Uganda | Journal article | environmental health | scientists, journalists, public | interviews, focus groups (n=35) |
| Besley, Dudo & Yuan, 2018 | USA | Journal article | STEM | scientists | surveys (n=1685) |
| Dijkstra, Roefs & Drossaert, 2015 | The Netherlands | Journal article | biomedical research | scientists, journalists | interviews (scientists n=21 science journalists n=14) |

| | | | | | |
|---|---|---|---|---|---|
| Dudo, 2015 | USA | Journal article | history of the science-media relationship | scientists, journalists | literature review |
| Gerhards & Schäfer, 2009 | Germany, USA | Journal article | biotechnology, genomics | media (news articles) | literature review, media analysis |
| Kaye et al., 2011 | Uganda | Journal article | Health research | scientists, journalists | training workshops (scientists, n=80, journalists, n=24) |
| Koso, 2021 | Japan | Journal article | science-media relationship | universities and research institutes | surveys (n=180), in-depth interviews (n=6) |
| Larsson et al., 2019 | international comparison (21 countries) | Journal article | medicine | scientists | interviews (n=2), focus groups (n=14) and surveys (n=118) |
| Lo & Peters, 2015 | Taiwan, Germany | Journal article | life sciences | scientists | surveys (Taiwan n=270, Germany n=326) |
| Lutz et al., 2018 | Europe | Journal article | geoscience and hydrology | scientists, journalists | commentary based on the theory |
| Metcalfe, 2020 | Australia, Canada, Germany, India, Italy, Kenya, Mexico, South Africa, Spain, Sweden, UK | Journal article | COVID-19 | the perspective of authors on science-media relationship | diary studies, including observations of media |
| Meyer & Sandoe, 2012 | Denmark | Journal article | ethical aspects of science communication | scientists | practical ethical approach, interviews |
| Mogendorff et al., 2012 | The Netherlands | Journal article | plant science | scientists | interviews, discursive psychology |
| Olesk, 2021 | Estonia | Journal article | medialisation of science | scientists | interviews |
| Peters, 2007 | Germany | Book chapter | risk issues, climate change | scientists, journalists | surveys (different rounds, total N=568) |

| | | | | | |
|---|---|---|---|---|---|
| Peters et al., 2008 | Germany, France, Japan, UK, USA | Journal article | biomedical research | scientists | surveys (N=1354) |
| Peters, 2013 | cross-cultural | Journal article | natural science | scientists | analysis of surveys published earlier |
| Schiele, 2008 | international, Canada | Book chapter | History of the deficit model | none, theoretical overview | literature review |
| Van Witsen & Takahashi, 2018 | USA | Journal article | knowledge journalism (science & environmental) | theoretical perspective on knowledge journalism | literature review |

As *Table 1* shows, fourteen of the articles directly included perspectives from scientists through surveys, interviews or other types of participation, such as focus groups and training workshops. In contrast, only four of the articles directly included perspectives from journalists in the data collection for their study. Nevertheless, many articles that did not directly include scientists' or journalists' views based on empirical data also reflected on their roles and their relationship. These findings and reflections will be discussed for each topic separately in the section below. The included topics consist of reasons for engagement, roles of scientists and journalists and challenges and changes in the science-media relationship.

**Overview of literature from the second sample**

Table 2 provides an overview of the literature included in the second sample.

**Table 2**

*Overview of literature second round*

| Authors | country | Type of publication | focus | included stakeholders | Methods |
|---|---|---|---|---|---|
| Albaek (2011) | Denmark | Journal article | journalist-expert interactions | journalists, scientists | telephone survey with journalists (n=395) & scientists (n=346) |
| Ashwell (2016) | New Zealand | Journal article | Science journalists' use | Journalists, scientists, | interviews with journalists (n=6), |

| | | | | | |
|---|---|---|---|---|---|
| | | | of PR materials | science communication advisors | scientists (n=9) & science communication advisors (n=10) |
| Besley & Nisbeth (2011) | UK & USA | Journal article | scientists' perception of science communication | scientists | literature review + analysis of 2 surveys |
| Dunwoody, Brossard & Dudo (2009) | USA | Journal article | Biomedical: Stem cell research & epidemiology | scientists | survey (n=363) |
| Fahy & Nisbet (2011) | USA & UK | Journal article | Roles of science journalists | journalists and science writers | interviews (n=11) |
| Fleerackers et al (2021) | Canada & USA | Journal article | COVID-19 | media (news articles) | quantitative content analysis (n=521) |
| Giannoulis et al (2010) | Greece | Journal article | Environmental issues | (environmental) journalists | Q-methodology + interviews (n=23) |
| Ivanova et al (2013) | Germany | Journal article | Climate science | (climate) scientists | survey (n=1130) |
| Kolandai-Matchett et al. (2021) | New Zealand | Journal article | marine science | journalists and scientists | survey with journalists (n=93) and scientists (n=72) |
| Maillé et al (2010) | Canada | Journal article | Mercury pollution | journalists and scientists | interviews with journalists (n=10) and scientists (n=7) |
| Massarani et al. (2021) | International comparison (77 countries) | Journal article | COVID-19 | science journalists | survey (n=633) |
| McKinnon et al. (2018) | Australia | Journal article | Science journalists' use of PR materials | Journalists, scientists, science communication advisors | interviews with journalists (n=10), scientists (n=9) and science communication advisors (n=8) |
| Rödder (2009) | UK & Germany | Journal article | Genomics (Human Genome | scientists | content analysis news articles (Germany n=250, UK n=136) + |

| | | | | | |
|---|---|---|---|---|---|
| | | | Project) | | interviews with scientists (n not mentioned) |
| Rödder & Schäfer (2010) | Germany | Journal article | particle physics and human genomics | scientists | content analysis news articles (n=1569) + interviews with scientists (n not mentioned) |
| Schäfer & Painter (2020) | International comparison | Journal article | Climate change | journalists | literature review (n not mentioned) |
| Waddell et al. (2005) | Canada | Journal article | health science | journalists | interviews (n=12) |
| Williams & Gajevic (2013) | UK | Journal article | genomics (hybrid embryos) | journalists, scientists, press officers, opponents | content analysis news articles (n=427) + interviews (n=16) |

**Table 2** provides an overview of the 17 articles included in the second sample of this literature review. In this sample, perspectives of scientists were included in 12 articles and those of journalists in 11 articles, multiple articles included both these and/or other stakeholder perspectives.

## 3.2 Reasons for engagement

In the articles and book chapters about science-media interactions, several reasons for scientists to engage in interactions with media and the public were mentioned. Many of these reasons can be categorised as main arguments for scientists to engage in such interactions. In this review, the categorisation made by Fiorino (1990) consisting of substantive, normative and instrumental arguments was used as a base, and additional categories from the reviewed literature were added.

Fiorino (1990) described arguments for citizen participation in science and technology risk assessment. These broad categories have been applied also in other contexts (Wilsdon & Willis, 2004). Substantive arguments are based on the ability of laypeople to make valuable contributions to science when given the possibility to contribute. Normative arguments relate to democratic ideals, according to which

citizens are the best judge of their own interest and need scientific information to make decisions. Finally, instrumental arguments are based on the need for public support and legitimation for science (Fiorino, 1990).

As will be discussed in more detail below, in most articles, authors mentioned multiple reasons for science-media interactions, often belonging to different types of arguments. The categories that occurred most often were assessed as normative, instrumental, educational and economic arguments and arguments related to outside pressures to engage. Substantive arguments were also mentioned a few times and reasons related to the popularisation of science and the enjoyment that scientists themselves could get out of engaging with the public.

As mentioned before, normative arguments for scientists to engage with media and the public relate to democratic ideals. Arguments of this type were mentioned in ten of the included articles. Most normative arguments emphasised the need for communication because science plays an important role in democratic societies, as well as in addressing pressing global issues (Dijkstra et al., 2015; Gerhards & Schäfer, 2009; Meyer & Sandøe, 2012; Olesk, 2021; Van Witsen & Takahashi, 2018). In some articles, democratic ideals were understood as responsibility for scientists to help members of the public and policymakers understand the potential impact of their research (Appiah et al., 2020; Dijkstra et al., 2015; Peters, 2013). In relation to this, some authors stressed the importance of public communication about science to spark debates and help people to relate scientific topics to their own values (Besley et al., 2018; Larsson et al., 2019).

Ten of the articles contained instrumental arguments based on the need for public support to legitimise science. Dudo (2015) explained that near the end of the 20$^{th}$ century, the scientific community started to see that public dissemination of scientific information could help to preserve science by regaining credibility and gaining funding for scientific activities. This need for public legitimation of science remains an important reason for members of the scientific community to engage in public communication activities (Gerhards & Schäfer, 2009; Koso, 2021; Larsson et al., 2019; Lo & Peters, 2015; Olesk, 2021; Peters et al., 2008; Peters, 2013).

Economic arguments could be distinguished as a special type of instrumental argument for scientists to engage in public communication. Economic arguments concern the need to legitimise research among funders and to potentially increase funding for science (Allgaier et al., 2013; Dijkstra et al., 2015; Larsson et al., 2019; Meyer & Sandoe, 2012; Olesk, 2021; Peters, 2007;). Kaye et al. (2011) noted that these arguments do not only come from scientists but also from external stakeholders. For example, funders regularly ask scientists to include public engagement plans when applying for funding for their research. Another type of instrumental argument could be identified as well, which related to professional benefits for researchers of engaging in public communication of science. In several articles, authors suggested that public communication could help scientists to increase their status within their organisation and/or scientific community (Allgaier et al., 2013; Dijkstra et al., 2015; Larsson et al., 2019; Peters, 2007).

Substantive arguments, which related to the benefits that including public opinions in science can have for science itself, were mentioned in four articles. Substantive arguments that scientists mentioned included wanting to hear what others think about their research and to get a critical reflection of their work (Besley et al., 2018; Dijkstra et al., 2015). Van Witsen and Takahashi (2018) described good science journalism as an important additional form of knowledge production that can contribute to scientific knowledge. In contrast, Mogendorff et al. (2012) found that the plant scientists they interviewed cared about lay views but did not see the needs or benefits of involving them in their research practices.

For many scientists, educating people about science is one of the main reasons to engage in public communication. Arguments related to the potential to educate people through public communication were mentioned in six articles (Besley et al., 2018; Dijkstra et al., 2015; Larsson et al., 2019; Lo & Peters, 2015; Olesk, 2021; Van Witsen & Takahashi, 2018). Dijkstra et al. (2015) found that scientists and journalists even saw sharing knowledge as the main advantage of public communication about science for the public. Appiah et al. (2020) argued that interactions between scientists and journalists could also contribute to educating journalists about scientific topics, which in turn could lead to an increased interest to cover more scientific topics.

As the goal of education, the aim to use public communication to increase enthusiasm about science keeps recurring. In several articles, authors mentioned getting people interested or excited about science as reasons for scientists to interact with media and the public (Besley et al., 2018; Dijkstra et al., 2015; Dudo, 2015; Olesk, 2021). Appiah et al. (2020) argued that more direct interactions between scientists and the public, such as media interviews, could help to bridge the perceived gap between scientists and the public.

In various articles, authors described engaging in public communication activities as a professional responsibility or necessity for scientists (Allgaier et al., 2013; Besley et al., 2018; Dudo, 2015; Larsson et al., 2019; Olesk, 2021; Peters et al., 2008; Peters, 2013). For example, Allgaier et al. (2013; p.426) concluded that most neuroscientists see public communication as a moral obligation, adding that: "Even those researchers who reacted negatively to the media considered interactions both necessary and inevitable." This perceived necessity was also discussed concerning outside pressure on scientists to engage in public communication about science, for example, from research organisations and governments (Besley et al., 2018; Peters, 2013).

Dudo (2015) stressed that even though scientists often see public communication as a professional responsibility, many also enjoy this task. Olesk (2021) also mentioned enjoyment as a personal motive for scientists to participate in public communication. Dijkstra et al. (2015) found that both scientists and journalists mentioned personal enjoyment as a reason to engage in public communication of science.

There were only a few articles in which the authors mentioned reasons for journalists to interact with scientists. This included reasons related to democratic and educational arguments and the criterion of newsworthiness. As mentioned earlier, Dijkstra et al. (2015) found that educating the public about scientific topics and personal enjoyment were important reasons for journalists to report about science. When referring to the newsworthiness of scientific topics, Peters (2007) argued that journalists are mainly looking for a good story to tell. Appiah et al. (2020) stated that

journalists usually took the initiative to reach out to scientists, but this was mainly in relation to drastic situations. Similarly to normative arguments for scientists to engage in public communication, Van Witsen & Takahashi (2018) emphasised the need for knowledge-based journalism because of the increasing importance of science in society.

## Results from the second sample

The literature in the second sample showed similar trends in the reasons that were mentioned most often for scientists to interact with journalists. In their survey of scientists, Dunwoody, Brossard and Dudo (2009) found that the main predictors for scientists to interact with media were status, self-efficacy, formal training and intrinsic motivation. This intrinsic motivation included scientists' belief that they could influence people's understanding of science and its role in society (Dunwoody, Brossard & Dudo, 2009). Kolandai-Matchett et al. (2021) reported that marine scientists got personal satisfaction from collaborating with journalists and informing the public. This fits with normative and educational arguments for scientists to engage with the public. Interestingly, the analysis by Dunwoody, Brossard & Dudo (2009) also suggested that extrinsic rewards did not play a large role, suggesting that instrumental and economic arguments for interaction are less important.

Several articles in the new sample provided potential reasons for journalists to cover scientific topics. Albaek (2011, p.343-344) found that journalists in Denmark mostly contact researchers to get interpretations of their material or background information on a specific topic, to get "expert opinion rather than discuss research developments". Likewise, Kolandai-Matchett et al. (2021) noted that journalists mentioned accurate and clear reporting, educative stories and increased credibility as positive outcomes of working with scientists. Other positive outcomes included network development, knowledge gains, awards and interest and positive feedback from audiences (Kolandai-Matchett et al., 2021). Waddell et al. (2005) suggested that the possibility to influence policies may be a reason for journalists to interact with scientists. In contrast, Ashwell (2016) found that in New Zealand, journalists may choose not to specialise in science because they prefer topics that are more secure and over which they have more control.

## 3.3 Roles of scientists

Many different categorisations of the roles of scientists in science-media interactions have been created. In this literature review, a combination of the categorisations of Pielke (2007) and (Spruijt et al., 2013) was used as a basis, and other categories that occurred in the sample were added. The roles that occurred most frequently were those of expert (mentioned seven times), educator and promoter of science (both mentioned four times). Other roles that appeared more than once were those of pure or autonomous scientists, honest brokers of policy advice, critics and scientists that act as proactive public communicators. We will discuss how these roles were described below.

The role of the expert was described with some variation. This role sometimes occurs as part of the deficit model, in contrast to other roles, or as an older idea about the role of scientists in science-media interactions (Gerhards & Schäfer, 2009; Mogendorff et al., 2012; Schiele, 2008). There was not much elaboration on what this expert role entailed in these cases. In addition, in multiple articles, journalists described the role of scientists in science-media interactions as an expert role. In some cases, journalists described scientists as expert sources without much agency that they could use as a source of information for their own purposes (Peters, 2007; Van Witsen & Takahashi, 2018). In other cases, journalists ascribed a more active expert role to scientists. For example, Allgaier et al. (2013) and Peters (2013) acknowledged that scientists could actively engage with journalists and use their expert status to influence how a scientific topic is covered.

In some articles, the authors emphasised that scientists could have a critical expert role. For example, Lo and Peters (2015, p. 13) included the statement "With media contacts, scientists should use their expertise to criticise political, economic, and other decisions affecting society or make practical suggestions for action" in their study of perceptions of scientists about interactions with media. They found that both German and Taiwanese scientists agreed with this statement, though this agreement was larger among German scientists (Lo & Peters, 2015). Critical expert roles were also included by Dijkstra et al. (2015) and Olesk (2021) as part of the

theoretical background of their studies. Olesk (2021) described the critic as an expert who comments on research results, which was informed by study findings from Väliverronen (2001). Dijkstra et al. (2015) discussed results from Albaek (2011) study that concluded journalists mainly ask scientists to comment as critics to confirm the framing of news articles about science.

In his overview of the history of the deficit model of science communication, Schiele (2008) described how scientists went from fulfilling roles as public educators and popularisers of science to pure scientists and, later, to more interactive roles. He argued that after the second world war, there was an effort to distinguish scientists, in pure scientists roles, as separate from the public, with journalists as intermediaries between them (Schiele, 2008). After widespread criticism of the deficit model, there has been a shift towards a participatory model, focused on open dialogues between scientists and citizens, including more active roles of scientists in the public debates (Schiele, 2008). Even though there are historical shifts and developments in the science-society relationship, all of the aforementioned roles coexist and are still present in more recent literature.

In multiple articles, authors described the roles of scientists as popularisers of science, promoting their own research as well as a positive image of science in general (Gerhards & Schäfer, 2009; Lo & Peters, 2015; Lutz et al., 2018; Meyer & Sandoe, 2012; Olesk, 2021). The roles of scientists as educators in public debates about science also occurred a few times (Dijkstra et al., 2015; Lo & Peters, 2015; Peters, 3013). Peters (2013) argued that the main expectation of science journalism is that it should disseminate knowledge about science and make it widely accessible, making it important for scientists to take on an educational role when interacting with media.

The role of pure or autonomous scientists, who prefer not to interact with media and the public, recurred a few times (Kaye et al., 2011; Lo & Peters, 2015; Metcalfe et al., 2020). Metcalfe et al. (2020) explained that some scientists were hesitant to join the public debate about COVID-19, likely because it is considered a controversial and politicised topic, whereas others took the opportunity to gain public visibility by becoming spokespeople in media. The shift that Schiele (2008) described towards

more interactive roles for scientists in public debates was visible in other articles, especially in those published more recently (Besley et al., 2018; Larsson et al., 2019; Lutz et al., 2018). For example, Larsson et al. (2019) found that many of the surveyed scientists took on a proactive role, often contacting media multiple times a year. Lutz et al. (2018) described the potential of using social media to create a more democratic and participatory discussion between scientists and the public.

This call for democratisation of the science-media relationship resonates with other descriptions of more political roles for scientists. Peters et al. (2008) saw being an advocate of truth and rationality as a classical role for scientists in public debates. Resembling the role of scientists as honest brokers of policy advice, Dijkstra et al. (2015) described a role for scientists as sparring partners for journalists to help understand, interpret and explain complex scientific and political issues. They also stressed the importance of scientists giving professional instead of personal opinions in public debates related to their expertise (Dijkstra et al., 2015). Olesk (2021) included a similar role of scientists as advisors or advocates who make policy claims or comment on policy claims made by others.

## Results from the second sample

Of the roles that were distinguished earlier, the roles of scientists as experts and as popularizers or promoters of science reoccurred most prominently in the second sample (Albaek, 2011; Maillé et al, 2010; Williams & Gajevic, 2013). In addition, two articles focused on journalists' descriptions of scientists' roles. They both found that, according to journalists, scientists should provide checks and ensure accuracy in news reports (Albaek, 2011; Ashwell, 2016). Albaek (2011) also noted that the role of scientists has shifted from focussing on their own work towards providing an expert opinion, commenting on issues related to their area of expertise.

## 3.4 Roles of media producers

Like for the roles of scientists, there were various descriptions of roles that journalists and other media producers can have in the science-media relationship. Each article described the roles of journalists slightly differently, but in many cases, these descriptions resembled more commonly used typologies of journalists. The roles that occurred most often were gatekeeper, civic educator, watchdog and science populariser or cheerleader.

Dudo (2015) explained that the traditional role of science journalists was to be a gatekeeper who critically reviewed and disseminated news about science in accessible, instructive and interesting ways. Dijkstra et al. (2015) reported that the journalists they interviewed emphasised the need for science journalists to be very critical to provide correct and high-quality information about science. These types of critical gatekeeper and watchdog roles were also mentioned by Gerhards and Schäfer (2009), Lo and Peters (2015) and Lutz et al. (2018).

Peters (2007) showed that journalists preferred to have critical, independent roles, such as gatekeeper and watchdog, whereas scientists expected journalists to help them promote the goals and interests of science. Larsson et al. (2019) also mentioned that, concerning their own research, scientists sometimes found it difficult to understand the role of journalists as watchdogs and the importance of a free and critical press. Thus, many scientists seem to prefer it when journalists take on less critical, more supportive roles when reporting about science, such as a civic educator or "cheerleader", to promote and popularise science.

In a cheerleader role, journalists may see themselves as serving science to some extent (Peters et al., 2008). As popularisers of science, journalists can also help to justify and legitimise science (Schiele, 2008). As educators, journalists can take on a position to teach and inform a large public about scientific issues (Appiah, 2020; Peters, 2013). Lo and Peters (2015) found that both German and Taiwanese scientists agreed that journalists should educate the general public about science and the scientific process, thus taking on an educational role.

A few of the articles discussed roles for journalists as more neutral, independent reporters, chroniclers or intermediaries (Gerhards & Schäfer, 2009; Kaye et al., 2011; Peters, 2007; Schiele, 2008). In contrast, two other articles explicitly included political aspects in the role of journalists. Appiah et al. (2020) argued that journalists in Ghana and Uganda act as advocates for public health when they aim to educate the public on scientific issues related to this topic. According to Van Witsen and Takahashi (2018), journalists have a responsibility to broker between diverse science claims-makers, especially in politicised debates about scientific topics, such as climate change. These roles seem to correspond with the roles of issue advocate and honest broker of policy advice for scientists described earlier.

## Results from the second sample

The roles of journalists that were most common in the first sample, reoccurred often in the second sample as well. The roles of gatekeeper, watchdog and science populariser or cheerleader were mentioned multiple times (Maillé et al, 2010; McKinnon, 2018; Schäfer & Painter, 2020; Williams & Gajevic, 2013). Some articles focused on more specific tasks in their descriptions of journalists' roles. Albaek (2011) noted that journalists were the initiator of contact with scientists in 90% of the cases and usually contacted scientists they already knew. McKinnon (2018) named this reliance of journalists on a selected group of trustworthy sources 'trustportfolio'. Ashwell (2016) and Waddell et al. (2005) both emphasized journalists had responsibilities towards their audience as well as towards their sources. Serving the audience and reporting accurately were seen as the main tasks of journalists, but expectation management and being receptive towards expert sources is also part of their role (Ashwell, 2016; Waddel et al., 2005).

Some articles provided new categorizations of roles of journalists. Fahy and Nisbet (2011) discussed nine roles of science journalists in the changing media ecosystem that increasingly includes online environments. They found that the roles of curator, convener, public intellectual and civic educator become increasingly common. However, journalists still identified strongly with the roles of agenda-setter, conduit, reporter and watchdog as well. None of the journalists they interviewed identified

with the role of advocacy (Fahy & Nisbet, 2011). Giannoulis et al. (2010) focused on the roles of climate journalists in Greece. They identified three roles that are similar to earlier categorizations of roles of journalists in general. The "scientifically led, environmentally responsible" journalist is similar to an investigative journalist, the "environmental crusader" is similar to the populist mobilizer and the "impartial journalist" is similar to a classical disseminator (Giannoulis et al., 2010).

## 3.5 Changes in the science-media relationship

In this document's introduction, we mentioned two ongoing changes in the science-media relationship: the changing media landscape and the renewed interest in the science-media relationship due to the COVID-19 pandemic. Both of these changes were discussed in the articles in the literature review as well. The changing media landscape was one of the most mentioned changes, occurring in nine different articles, as described below in more detail. Changes related to the COVID-19 pandemic only occurred in one of the articles, but it is expected that this will be a dominant theme in literature that will be added to this living document later (Metcalfe et al., 2020). Another change that was included in various articles about the science-media relationship is the process of medialisation, which was mentioned explicitly in six articles and described implicitly in four more articles.

### Changing media landscape

The changing media landscape is comprised of multiple changes that occur together. Dudo (2015) provided an overview of changes in the science-media relationship, in which he paid special attention to how changes in the media landscape have affected this relationship. He argued that several changes weaken the traditional role of media as the primary source through which most people encounter science (Dudo, 2015). These changes include the increasing popularity of the internet and digital media, a decrease of interest in news about science and technology among citizens in the USA and a reduction of funding for news media and especially for science journalism (Dudo, 2015). He concluded that new media may fundamentally transform the relationship between science and society, but it is unclear what this transformation will entail. Even though these changes are still ongoing, new insights on how new

media transform science-media interactions have been published.

Larsson et al. (2019) argued that technologies like the internet and social media platforms changed and is still changing the working conditions of news media production. Because of the increased opportunities to publish more often on different platforms, there are more deadlines with less time to research, write and check news stories (Larsson et al., 2019). Larsson et al. (2019) mentioned worries that these developments, combined with restructuring and staff cuts at newspapers, could diminish the quality of science reports. Appiah et al. (2020) also saw financial pressures and a lack of time for journalists and scientists as barriers to effective science communication.

Metcalfe et al. (2020) came to the more positive conclusion that, because of their perceived credibility, traditional media outlets remain an important source of information for many people, especially during a crisis. Peters et al. (2008) also noted some positive changes in the media landscape related to science journalism. They argued that it is plausible that science journalism has professionalised, leading to more media coverage of science of good quality (Peters, 2008). Peters (2013) echoed some of the worries about the popularity of internet media and underfunding of traditional media leading to a decrease in science journalism and its quality, but he also saw new opportunities. These opportunities include using online communities and social media for more dialogic forms of science communication and increased participation of citizens in debates about scientific topics and their implications (Peters, 2013).

Van Witsen and Takahashi (2018) discussed how the changing media landscape had affected science journalism and environmental journalism. They argued that in addition to increased pressures on journalists due to reductions in funding and increased numbers of deadlines, settled routines and assumptions in journalism are changing (Van Witsen & Takahashi, 2018). These include the professional monopoly that journalism used to have over news reporting, the daily speed of the news cycle, steady patterns of news consumption and the separation of reporting and opinion (Van Witsen & Takahashi, 2018). The authors also stated that these developments led to blurring lines between journalism and other forms of knowledge production.

They also proposed a new role of "ecological moderniser" for environmental journalists to adapt to these developments (Van Witsen & Takahashi, 2018, p.726).

**Medialisation**

The second process of change that has strongly affected the science-media relationship is the medialisation of science, sometimes also referred to as mediatisation (e.g. Olesk, 2021). The introduction of the concept of medialisation of science is usually attributed to Weingart (2001; 2012) (Allgaier et al., 2013). The medialisation of the science framework focuses on science's perspective in the science-media relationship (Allgaier et al., 2013). It argues that the scientific community becomes increasingly oriented towards mass media and public visibility, mainly because of the need for the public legitimisation of science (Allgaier et al., 2013). This increasing reliance of scientists on mass media and the increasing incentives for scientists to interact with media is also discussed by Gerhards & Schäfer (2009), Meyer & Sandøe (2012) and Peters et al. (2008).

Some authors also described the increased media attention for scientific issues, as part of the science medialisation process, from the media perspective (Kaye et al., 2011). According to these authors, it also includes an increasing institutionalisation and professionalisation of science communication activities within universities and other research organisations (Besley et al., 2018; Koso, 2021). The main worry of the medialisation of science framework is that there is a tension between the rules and values of science and those of media and that scientists may increasingly use rules and values of media in decisions about their research, instead of relying on scientific values (Allgaier et al., 2013; Dijkstra et al., 2015).

On the positive side, scientists' increasing orientation towards the media could also lead to an increased understanding and better collaboration between scientists and journalists (Allgaier et al., 2013). Through their interviews with neuroscientists, Allgaier et al. (2013) found support for this positive effect; the scientists knew more about the norms and processes of journalism than scientists in older studies on this topic. In addition, they found that scientists used this knowledge to try to further their career within their organisation and their socio-political environment, but not for the

selection of research topics and methods (Allgaier et al., 2013).

Most studies about the medialisation of science have focused on scientists in Western societies (Koso, 2021). Non-Western perspectives were added in the studies by Lo and Peters (2015), who compared how medialised German and Taiwanese life scientists were, and Koso (2021), who studied how Japanese research organisations adapted to the unique media landscape in Japan. Lo and Peters (2015) concluded that Taiwanese life scientists were less medialised than their German colleagues. The surveyed Taiwanese scientists were less likely to prioritise interactions with media, adapt to journalistic styles, and discuss the context, problems, and uncertainties of their research (Lo and Peters, 2015).

Koso (2021) found that Japanese research organisations are somewhat medialised in that they adapt their ways of communicating about science to the preferences of local press clubs, which are an important player in the media landscape in Japan. However, the indicators of professionalisation and institutionalisation that are related to the medialisation of science in Western countries were not observed in Japan (Koso, 2021). This leads to the conclusion that there can be different types of science medialisation in different cultural contexts.

**COVID-19 related changes**

During the COVID-19 pandemic, the importance of science for society and the need for high-quality science journalism have become especially apparent, as was already mentioned in ENJOIs Grant Agreement (2020). Due to societal relevance and the newness of the virus, there was a strong need for information, resulting in an overload of communication of varying quality. This overload was also described as an "infodemic" (Ghebreyesus, 2020). The demand for scientific information about the virus also led to a large increase in research made available in pre-prints before peer review and publication (Grant Agreement, 2020). This was beneficial for scientists since they could build forth on the work of their colleagues quicker, but these pre-prints were also distributed via (social) media, where they added to the overload of information and confusion.

Metcalfe et al. (2020) used auto-ethnographic techniques to compare observations

of communication about science related to COVID-19 in eleven countries during the early stages of the pandemic. They identified four phases in media communication about COVID-19, corresponding to different phases in the spread of the virus. Within each country, the first phase was characterised by a rise in COVID-19 infections and concern among the public. As a reaction, all media focused on informing people about the virus and its symptoms. In the second phase, the media mainly focused on government reactions and attempts to flatten the curve, which were often explained through the use of metaphors. During the third phase, media coverage often becomes more critical, focussing on the impacts of lockdowns and other restrictions on citizens and economies. The fourth phase, which occurred at the end of May 2020 in most included countries, was characterised by easing restrictions and media discussions about how to get back to a "new normal" (Metcalfe et al., 2020, p.12).

Metcalfe et al. (2020) also found that debates about science quickly shifted across countries during the COVID-19 pandemic. The mostly debated themes seemed to correspond to the four phases in media communication. They occurred at different times in each country, depending on the status of the spread of the virus. The authors also found an initial increase in trust in science and governments during the beginning of the pandemic. This trust seemed to decrease again in some countries when restrictions were eased. In addition, they noted that media reporting often drew attention to disagreements among experts, which may have contributed to the decrease in trust in science over time.

## Results from the second sample

The effect of the changing media landscape on science-media interactions reoccurred often in the second sample, mainly in relation to the increased pressure on a decreasing number of science journalists. These articles warned that these changes may lead to journalists increasingly depending on press release material and sources and becoming less critical of them (Ashwell, 2016; McKinnon et al, 2018; Schäfer & Painter, 2020). Schäfer and Painter (2020) emphasised that the trends of the growing importance of online media, crisis in news media and pluralization of content vary per country, depending on politics and media culture.

Several articles focused on the process of medialisation. Ivanova et al. (2013) conducted a survey to study how medialised German climate scientists are, focussing on the dimensions of media interactions and media adaptations. They concluded that experienced, high-ranking scientists have more media interactions, whereas less experienced researchers seem to be slightly more willing to adapt to media interest. They also noted that institutions seem to play an important role in medialisation processes, with PR departments passing requests for media contact on to scientists (Ivanova et al., 2013). Similarly, Williams and Gajevic (2013) noted that the professionalisation of science PR is an important part of the medialisation process, using the example of the UK science media centre aiming to get key messages about hybrid embryo research across via journalists. They argue that science journalists depend too much on certain sources such as the science media centre, which makes news coverage more homogeneous and less critical (Williams & Gajevic, 2013).

Rödder (2009) studied the medialisation of the Human Genome project and found that all four included indicators of medialisation - press conferences, media publications before scientific publications, visible scientists and intertwining of scientific discourse with political, commercial and ethical discourses - were present in this case. Rödder and Schäfer (2010) compared the medialisation of particle physics research and human genome research along two dimensions: changes in media coverage and repercussions of the coverage. They concluded that despite medialisation being present for human genomic research, it is still rare for other topics like particle physics research. The extent of medialisation seems to be dependent on topic, time and material, and only applies for a few visible scientists (Rödder & Schäfer, 2010).

Finally, two articles in the second sample extensively discussed changes in the science-media relationship related to the COVID-19 pandemic. Massarani et al. (2010) conducted a large-scale survey asking journalists about the effect of the pandemic on their work. Journalists mentioned several positive aspects, including a larger public interest in and understanding of science, more job opportunities and new challenges in their work. Negative aspects that were mentioned included the

increased workload, exhaustive coverage of one topic and difficulties related to dealing with lockdowns. Regarding the effects of the pandemic on their interactions with scientists, journalists were divided but somewhat positive, with 37% finding scientists more open and talkative and 27% finding them more cautious, and 48% finding scientists more easily available (Massarani et al, 2021).

More than half of the science journalists who participated in the study by Massarani et al. (2021) used preprint articles, and 59% treated them differently, for example by stating the research had not been peer-reviewed. Fleerackers et al. (2021) studied such practices in the use of preprints about COVID-19. They found that many providers of science news used the 100 most-mentioned COVID-19 related preprints and many included a hyperlink to the preprint that was used. However, in many cases the news articles did not mention the research article they used was a preprint and 40% of the stories did not frame the preprints as uncertain. When preprints were framed as uncertain this was usually done by mentioning the research was not peer-reviewed (Fleerackers et al, 2021).

## 3.6 Challenges and potential solutions

Next to these changes, which have both positive and negative effects on science-media interactions, various authors discussed specific challenges, as described in more detail below. Some overarching themes could be identified among the different challenges in science-media interactions. These themes are: skills and training, lack of resources, collaboration, negative reactions and quality of science news coverage. In addition, two articles focused on broader challenges related to scientific research about the science-media relationship (Gerhards & Schäfer, 2009; Olesk, 2021). Two other challenges that were mentioned in the literature sample, that did not fit within any of the themes, were conflicts of interest of scientists appearing in media (Larsson et al., 2019) and a perceived lack of interest in science among the public of news media (Appiah et al., 2020).

Different stakeholders in the science-media relationship described challenges related to skills and training. Appiah et al. (2020) organised focus groups with scientists,

journalists and citizens from Ghana and Uganda in which they asked them about perceived challenges in science-media interactions. The challenges they identified included a lack of communication skills and training and a tendency to use complex language among scientists (Appiah et al., 2020). Kaye et al. (2011) found that both scientists and journalists agreed that scientists lacked knowledge about how to communicate their research. The main proposed solution for this problem was to offer communication or media training for scientists (Appiah et al., 2020; Kaye et al., 2011).

Another challenge related to skills and training, identified by Appiah et al. (2020), was a lack of education among the public about environmental health topics. A proposed solution to increase public understanding and interest was to simplify scientific language and to add narratives and human elements to news stories about science (Appiah et al., 2020). For journalists, Larsson et al. (2019) found that medical experts saw journalists' lack of basic medical knowledge as one of the main challenges in science-media interactions. They also proposed some potential solutions, including building up a network of medical scientists that are available for journalists and organising regular meetings between scientists and journalists (Larsson et al., 2019).

In addition to a lack of skills and training, a lack of resources for scientists and journalists was a commonly mentioned challenge. Allgaier et al. (2013), Dijkstra et al. (2015) and Larsson et al. (2019) all mentioned time constraints as a limiting factor for science-media interactions. Allgaier et al. (2013) found that scientists saw the need to disrupt their routines and make time for interactions with media as a barrier. The results by Dijkstra et al. (2015) showed that journalists also experienced the lack of time of scientists as a problem. Larsson et al. (2019) saw the short deadlines that journalists have to adhere to as a potential threat to the quality of news reports about science.

Next to a lack of time, a lack of opportunities for science-media interactions (Kaye et al., 2011) and a lack of support for scientists within their institutes to engage with media and the public (Koso, 2021) were discussed. The main solutions to solve problems related to lacking resources, according to those authors, consisted of various ways to make more resources available. For example, by improving the

valorisation of science communication activities through increased salaries or rewards (Kaye et al., 2011) or by hiring professionals, such as public communication officers, to support science communication activities (Koso, 2021).

Several challenges related to collaborations between scientists and journalists were discussed. Appiah et al. (2020) saw a lack of collaboration between scientists and journalists as one of the main barriers in science communication about public health issues. Dudo (2015) explained that interactions between scientists and journalists have historically often been shaped by mutual mistrust, ambivalence or even disdain. It seems that similar problems are still present. Kaye et al. (2011) noticed that journalists felt that senior scientists, in particular, looked down on them, whereas young scientists believed that journalists often rejected their efforts to communicate and would rather interact with senior scientists.

Several articles focused specifically on understanding the dominant perception of a gap between science and society (Peters, 2007; Peters et al., 2008; Peters, 2013). Peters' perspective is that the relationship between scientists and journalists is less troublesome than it is often portrayed in the scientific literature about this topic. Peters (2007) conducted surveys among scientists and journalists in Germany and found that they are generally satisfied with their interactions with each other. Nevertheless, scientists and journalists had different expectations of what their interactions should be like in an ideal situation.

Peters (2007) saw disagreements about who should have control over news messages about science as the main cause for misunderstandings between scientists and journalists. Similarly, Dijkstra et al. (2015) attributed misunderstandings between scientists and journalists to scientists being unaware of the expectations of journalists they interact with. They proposed ways of enhancing mutual understanding between scientists and journalists as a potential solution to this problem (Dijkstra et al., 2015).

Besley et al. (2018) observed that there is a widespread wish for scientists to engage more in public communication and suggested that it might help to let scientists think about their specific communication objectives. In contrast, Peters et al. (2008)

emphasised the need for strong science journalism to counterbalance the increasingly strategic self-presentation of scientists. Peters (2007) argued that general social competencies might be enough to help scientists and journalists deal with their differences and have positive interactions.

Negative perceptions of reports about science and previous negative experiences can be a large barrier for future science-media interactions. Allgaier et al. (2013) found that the perceived risks of critical coverage, peer criticism and other negative reactions to news about their research were among the main perceived problems of interacting with media that scientists identified. Dijkstra et al. (2015) and Larsson et al. (2019) also mentioned the risk of peer criticism as an obstacle to participating in science-media interactions.

Another main problem that Allgaier et al. (2013) identified was science news's perceived quality (or lack thereof), including issues with accuracy, bias, exaggeration, and raising false hopes. This problem was also mentioned by Larsson et al. (2019), who specifically emphasised the use of unreliable headlines and the choice of topic or angles as issues with the quality of news about medical science. In addition to the perceived lack of quality of news about science, some scientists unfortunately also had negative experiences when interacting with journalists themselves. Both Besley et al. (2018) and Dijkstra et al. (2015) found that previous negative experiences can be an important reason for scientists being hesitant about future media interactions.

Again, enhancing mutual understanding between scientists and journalists, creating networks of scientists and journalists to regularly interact with each other and thinking about science communication goals might help to solve these problems (Besley et al., 2018; Dijkstra et al., 2015; Larsson et al., 2019). In addition, Larsson et al. (2019) proposed training for journalists to improve their basic medical (or scientific) knowledge as a potential way to increase the quality of news reports.

## Results from the second sample

Like in the first sample, challenges related to a lack of skills and training and a lack of resources for science communication recurred in multiple articles (Maillé et al, 2010;

McKinnon et al., 2018; Williams &Gajevic, 2013). Several articles also mentioned scientists' and journalists' disappointment with the quality of science news coverage (Maillé et al., 2010; Kolandai-Matchett et al, 2021; Williams & Gajevic, 2013).

Challenges in the collaboration between scientists and journalists were discussed often (Giannoulis et al., 2011; Maillé et al., 2010; Kolandai-Matchett et al., 2021; Williams & Gajevic, 2013). Maillé et al. (2010) reported about several misunderstandings between scientists and journalists due to differences in their roles, including the speed required for news media, scientists' dissatisfaction with the lack of reporting about processes of science and methodology, and journalists' dissatisfaction with the usually passive role of scientists.

McKinnon et al (2018) reported that the relationship between scientists and journalists and quality of science reporting are generally good, but they fear that science journalists rely too much on a select number of trusted sources and PR material. Williams & Gajevic (2013) also mentioned the risk of scientists becoming too dependent on sources and becoming too uncritical towards these sources. McKinnon et al (2018) propose that fostering a symbiotic relationship could help to prevent that.

Kolandai-Matchett et al. (2021) found that marine scientists and journalists experienced similar problems in their relationship, but for different reasons. They provide several examples of this, such as scientists' wish to revise inaccuracies before publication and journalists' frustration with this, or journalists' difficulties with understanding jargon and scientists' frustration with oversimplification in news reports. Kolandai-Matchett et al (2021) also provide several solutions for the challenges they identified, including the creation of institutional policies to support direct interactions between scientists and journalists, training components and building mutual trust and respect.

# 4. DISCUSSION

In this literature review, we focused on several aspects of the science-media relationship to better understand the quality of interactions between scientists and media. The overviews of reasons for engagement in science-media interactions and the roles of scientists and journalists in these interactions offer insights into how active collaborations between scientists and media producers can improve accuracy in science communication.

The abundance of arguments and reasons for engagement in science-media interactions that were described in the literature shows that many scientists and media producers are aware of the benefits of science communication and science journalism. In addition to arguments related to outside pressures, legitimisation of research, and financial and professional benefits, arguments related to the inherent benefits of science-media interactions were also made. These include personal enjoyment of science communication activities, but also normative, educational and substantive arguments. Moreover, several studies found that scientists and journalists generally have a positive perception of their interactions (e.g. Dijkstra et al., 2015; Kaye et al., 2011; Peters, 2007).

Scientists' roles in science-media interactions were most often described in the literature as expert, educator or promotor of science roles. Interestingly, journalists most often described scientists as experts who simply provide information or take on more active and critical expert roles (e.g., Allgaier et al., 2013; Peters, 2013; Peters, 2007; Van Witsen & Takahashi, 2018). The roles of journalists were most often described as gatekeeper, civic educator, watchdog and science populariser or cheerleader. Various articles showed that journalists tend to describe their roles as critical and independent, whereas scientists prefer journalists to take on more supportive roles, such as civic educators or science popularisers (e.g. Peters, 2007; Larsson et al., 2019). This disconnection between the perceived roles is likely related to scientists and journalists' different beliefs about who should be in control of news about science (Peters, 2007). Creating mutual understanding among scientists and journalists about their roles might help to create more accurate scientific communication.

In order to foster and improve interactions between scientists and media producers, such as journalists, it is important to understand changes and challenges that affect the science-media relationship. The main changes currently at play are the medialisation of science and the changes in the media landscape. These changes led to various challenges, including dealing with a lack of skills, training, time and resources of both scientists and media producers. Luckily, potential solutions to these challenges have been identified as well. The solutions that are proposed most often are to provide training for scientists and journalists, create networks for continuous collaboration, and find new ways of working to adapt to the ongoing changes.

Since the last two years, the COVID-19 pandemic has led to new changes and challenges in science-media interactions. In addition to the challenges of dealing with highly uncertain scientific information, the increasing use of pre-prints and the quick developments in providing as much information as possible, often by (general) journalists who are not specialised or have a background in science, the pandemic has also drawn attention to the pressing need for high-quality science journalism. It remains to be seen how these changes and challenges will develop further and what the long-term effects will be.

The inclusion of the second sample of literature provided more information about the science-media relationship. The additional literature mostly confirmed the trends discussed above and provided new insights that provide more depth and nuance. Regarding reasons for engagement, the literature from the second sample indicated that intrinsic motivations are especially important in scientists' decisions to engage with media and the public. For journalists the main motivations to engage with scientists are to provide their audience with accurate and educative information or to potentially influence policy, whereas the uncertainty and lack of control demotivate them to cover scientific topics.

The types of roles of scientists and journalists that were mentioned most often in the first sample remained important in the literature of the second sample. The articles

also provided more evidence for the disconnect between scientists' and journalists' perception of their own and each other's roles. This remains a potential cause of challenges in the collaboration between scientists and journalists, as exemplified by the misunderstandings discussed by Maillé et al. (2010) and Kolandai-Matchett et al. (2021). Challenges related to a lack of training, skills and resources for both scientists and journalists recurred as well. A new challenge that was identified relates to science journalists increasing dependence on a limited amount of sources and PR material (McKinnon, 2018; Williams & Gajevic, 2013).

Ivanova et al. (2013) and Williams & Gajevic (2013) both highlighted the importance of PR departments and institutions in the process of medialisation. Rödder (2009) and Rödder and Schäfer (2010) showed that indicators of medialisation are clearly present in some cases, but rare for many other scientific topics. According to Rödder and Schäfer (2010), medialisation seems to be dependent on context and only applies for a few visible scientists.

Based on the new articles by Massarani et al. (2021) and Fleerackers et al. (2021) the COVID-19 pandemic seems to have both positive and negative effects on science-media interactions. Despite the increased workload and adapting to lockdowns, many journalists found scientists to be more easily available and more open and talkative during the pandemic (Massarani et al, 2021). The COVID-19 pandemic also increased journalists' use of preprints in their news reports, even though journalists did not always indicate they were discussing a preprint and what that means.

# 5. CONCLUSION

The first research question we addressed in this literature review was: *How can active collaborations between scientists and media producers improve accuracy in science communication?* Our analysis of the articles and book chapters in the first sample showed that, even though most scientists and journalists believe it is important and beneficial to engage in public communication of science, scientists frequently perceive problems with accuracy in news reports about their research. A proposed solution for this problem is to enhance mutual understanding between scientists and journalists. This may be done by improving the understanding of the roles and expectations of scientists and journalists in science-media interactions. The second round of analysis confirmed these findings and provided a more nuanced insight in the science-media relationship.

The second research question was: *How can interactions between scientists and media producers be fostered and improved?* Many authors noted that the relationship between scientists and media producers has already improved in the past few decades. The process of medialisation of science and changes in the media landscape have had both positive and negative effects on science-media interactions. Findings from the second sample deepened insights in the medialisation process. The main challenges for scientists and journalists include dealing with a lack of skills, training, time and resources for science communication activities. In addition to various ways of providing the necessary training and resources, a proposed solution to improve interactions between scientists and media producers is to create networks for continuous collaboration and, for example, to install institutional policies to support both journalists and researchers.

Finally, the COVID-19 pandemic has reaffirmed the necessity for high-quality science communication and science journalism. It has also led to new challenges, such as the necessity to deal with quick developments and high levels of uncertainty in scientific information. Because of the pressing need for information and quick scientific developments, there has been increasing use of pre-prints and a need for journalists without specialisation or background in science to cover complicated scientific topics. The pressure on journalists to work on more topics with fewer

resources increased.

We expect many new insights about the science-media relationship and changes and challenges which are currently happening to be published in the near future. Therefore, in the final year of the ENJOI project, we will continue to review newer literature about the science-media interactions which will include insights into the effects of the COVID-19 pandemic . In addition, as suggested in the mid-term review, we will aim to add an additional analysis of studies researching the situation in the countries Italy, Portugal and Spain and which have been published in these languages. We believe that such additional and specific research, which can be conducted with help of the ENJOI partners who master these languages, can enrich our current findings. The current literature review shows that the majority of studies about the science-media interactions have not collected data from these countries while the focus of ENJOI is mainly on the developments in science journalism and science communication in these countries.

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# APPENDIX 1: Review form

| Category | Space to fill in per article |
|---|---|
| Title, authors and year of publication | |
| Abstract | |
| Summary for literature review | |
| Type of literature<br>e.g. book chapter, conference paper, journal article, report, thesis | |
| Country | |
| Focus or case<br>AI, climate change, COVID-19, general study or other | |
| Perspective & included stakeholders | |
| Type of study & methods<br>Methods, sample, main questions/hypotheses | |
| Main results & conclusions | |
| Science-media relationship<br>How is it discussed? | |
| Type & perception of the relationship<br>E.g. hierarchical, interactive, positive, negative, ambivalent, neutral | |
| Reason for interaction<br>Cultural, democratic/normative, economic, educational, substantive, instrumental, necessity/outside pressure, popularisation | |
| Role of journalists<br>Agenda-setter, cheerleader, civic educator, conduit, convenor, curator, gatekeeper, investigative reporter, public intellectual | |
| Role of scientists<br>Expert, educator, promotor of science, pure/autonomous | |

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| | |
|---|---|
| scientist, science arbiter, issue advocate, honest broker of policy advice | |
| Role of other stakeholders? | |
| Type and role of scientific information<br>Explanatory, illustrative, argumentative, medialised | |
| Science communication theories<br>Which are mentioned, and how are they discussed? | |
| Models, frameworks, theories used<br>Contextual, science-in-society model, deficit model, mode 2/mode 3 science, networked model, open science, public understanding of science, RRI, scientific literacy, systems approach, transaction/dialogue model, upstream engagement | |
| Concepts mentioned<br>Accuracy, bias, complexity, contestation of expertise, credibility, engagement, mis- and disinformation, risk, scientific knowledge, SPIs, trust, uncertainty | |
| Processes mentioned<br>Changing media landscape, underfunding of (science) journalism, polarisation | |
| Other comments | |
| Interesting literature from references | |