Designing Digital Content to Support Science Journalism

Neil Maiden

City, University of London, London, UK, N.A.M.Maiden@city.ac.uk

Konstantinos Zachos

City, University of London, London, UK, K.Zachos@city.ac.uk

Suzanne Franks

City, University of London, London, UK, Suzanne.Franks.1@city.ac.uk

Rebecca Wells

City, University of London, London, UK, Rebecca.Wells.1@city.ac.uk

Samantha Stallard

City, University of London, London, UK, Samantha.Stallard@cass.city.ac.uk

ABSTRACT

Journalists need to become more effective at communicating science and countering post-truth activities that seek to undermine scientific processes and evidence. Digital support for journalists when investigating and writing about science-related topics is one means of improving this science communication. However, little bespoke digital support is available. This paper reports the research and development of one new form of such digital support. During a participatory design process, experienced science journalists and other professionals were interviewed about their challenges experienced and understanding of good practices in science journalism. These challenges and good practices informed the development of a prototype of a new form of digital tool that was evaluated by journalists without specialist science training. A new version of the prototype, called *INQUEST*, was implemented to automate some parts of good practices in order to augment journalists' capabilities. These practices included the retrieval of science information from diverse sources, targeting different science audiences, and providing different forms of guidance for explaining science to the target audience. This prototype is presented, and an early evaluation of it is reported.

CCS CONCEPTS

• Human-centered computing • Interaction design • Empirical studies in interaction design

KEYWORDS

Science communication, science journalism, audience segments, digital prototyping, participatory design

1 Introduction

We are now living in what many describe as a post-truth world [10]. Post-truth activities can be defined as the public burial of objective facts by an avalanche of media content intended to appeal to emotion and personal belief [23]. Examples include the invention of so-called alternative facts introduced into public discourse after the Trump inauguration in 2017 [50], and challenges to traditional forms of expertise exemplified by a UK politician's statement that people had had enough of experts during the 2016 EU Referendum campaign [33]. Many post-truth activities are perceived as an increasing risk to the well-being of democratic society [3], diminishing trust in political discourse, discouraging practices shown to keep people healthy, and blocking the bold steps needed to tackle the climate crisis [1].

Many discussions about post-truth activities focus on the credibility and reliability of science. This, in turn, affects different forms of science communication [7], including science journalism, which has frequently been in the eye of the storm because of reported misinformation and the dissemination of unreliable material. Wider pressures on journalism arising from the digital upheaval of the past decades [41] have in turn meant that, for economic reasons, science journalists have been stretched ever further to deliver in a multi-platform world. Over the same period, concerns have emerged that overall numbers of journalists in this specialism are diminishing [19] [40] [42]. Science has been reported to be a lower priority for most media compared to other subjects such as politics [42]. This has reduced the resources available to reach all of the audiences that should be informed by science when making democratic decisions [11], challenge fake science and interrogate science policy and findings effectively [11] [17]. Although some argue that science coverage has a higher media profile since the late 1990s, and that science journalism has increased in proportion to coverage of other subjects [42] [51], the current worldwide crisis due to the COVID-19 pandemic and the associated infodemic of false information has highlighted more than ever the need for trustworthy news on scientific and medical matters [27].

In this paper, we argue that the growth of post-truth activities imposes at least two specific demands on science journalism. The first is that science journalism needs to communicate to the general public so that citizens will be able to make informed democratic decisions about the important science-related societal, environmental, and political challenges facing the world. This requires more journalists than at present, and not just those that currently specialize in science journalism, to write about and communicate effectively on science-related topics. The second, which follows from the first, is that journalists have to communicate science-related topics to audiences that engage with science only rarely, and use channels frequented by these audiences to do so. Studies in the US and Europe have revealed large audience segments that are disengaged with or only moderately interested in science news [4] [12] [43], in this post-truth world, people in them often form incorrect views about science from a growing multiplicity of alternative and often unreliable sources.

New forms of digital support have the potential to enable journalists who do not specialize in science to write about and communicate science-related topics to reach these wider audiences. As well as assisting journalists during the COVID-19 crisis, this support could, e.g., aid regional broadcast journalists to communicate the local effects of climate change, and freelance journalists commissioned to write an article about the impact of the non-take-up of measles vaccine on school attendance. At the moment, however, there is little bespoke digital support for these forms of science journalism, especially for journalists who are not specialists.

Therefore, in response, this paper reports the design of a new digital tool to support journalists without science training to communicate more effectively about three challenges facing the world – the climate crisis, vaccine denial, and artificial intelligence in the workplace. The remainder of the paper is in 6 sections. The next two report definitions and key challenges facing science communication and journalism, and the few existing digital tools to support journalists to write stories. Subsequent sections report the key stages of a participatory design process. Interviews were held with 18 expert science journalists and communicators to discover the challenges facing science journalism and discuss potential opportunities for digital technologies to support science journalism. Using results from these interviews, a new digital prototype called *INQUEST* was designed, and features and content for the prototype were developed. Journalists with no science journalism expertise provided formative feedback to improve these features and content. The paper ends by presenting a first version of the *INQUEST* prototype, contrasting its features to existing digital tools for science journalism, and reflecting on the research contributions and prototype's implications for supporting science journalism.

2 Science Communication and Journalism

Science communication is defined as the organized, explicit and intended actions to communicate scientific knowledge, methodology, processes, or practices in settings where non-scientists are a recognized part of the audience [22]. It includes efforts to communicate the culture of science [9], enable laypeople and others with expertise outside of science to communicate about science [35], challenge science [14] [17], and engage through new and emerging formats such as social media, science festivals, events, comedy, and storytelling [25]. Most communication of science does not flow directly from scientists to the public. Instead, it passes through communicators such as journalists using mainstream media channels – channels that remain important portals through which science news is still consumed and trusted [2].

However, new digital technologies mean that these traditional forms of information exchange have been challenged [14]. In the world of science, as in so many other disciplines, social media technologies have opened up new channels by which people receive news. As a consequence, post-truth groups such as *Stop Mandatory Vaccination* and agencies like the *Heartland Institute* use these direct means of communication to circumvent mainstream media and share disinformation that contradicts scientific evidence and undermines scientific process (e.g. [18]). To counter these challenges to science, the authors of this paper argue that journalists need to evolve their practices to communicate more effectively to wider audiences using both mainstream and social media channels.

Unsurprisingly, most journalists, on their own, lack the breadth and depth of scientific knowledge needed to communicate science effectively themselves. The vast majority of journalists come from an arts humanities or social science background. Out of the estimated 400,000 journalists in the European Union in 2018, only 2,500 were represented by EUJSA, the EU's Science Journalists' Association. One solution is to talk more with scientists. However, scientists and journalists often struggle to interact effectively, in part because both lack the time needed to communicate, but also because journalists also lack the time to discover and examine scientific journals and other sources as news organizations reduce staff numbers to remain competitive in the age of digitalized news production [31]. Moreover, unsurprisingly, most journalists work using news rather than scientific values to short deadlines (e.g. [14] [20] [28]) that make it difficult to write effectively about complicated science-related stories [46]. Journalists who cover scientific stories are often drawn towards dramatic conclusions, positive results, bias and sensationalism [11] [42] [45]. As a consequence, senior figures in science have spoken about the paucity of effective reporting of science-related stories. For example, the Head of UK Research Councils drew attention to the way that science is reported when general journalists are involved, and called for improvements [8].

In this paper, we argue that non-specialist journalists can benefit from new forms of bespoke support to respond to the changing landscape of science journalism – support to understand science more effectively, discover scientific information related to stories, and communicate it to less engaged audiences in our societies more effectively – all within the constraints and pressures of modern newsrooms. New and bespoke digital capabilities have the potential to provide these new forms of support.

3 Digital Support for Journalists

The growing digitization of news production and consumption has enabled and been impacted by different forms of both automation of and digital support for journalists work. Many of these forms are now well-documented. They include the use of automation to verify social media sources (e.g. [54]), detect deep-fakes (e.g. [48]), and algorithmic journalism (e.g. [30]) for stories reporting more quantitative news such as sport and finance. Automation can also empower news consumers, for example to personalize their consumption to specific sources and topics (e.g. [6]).

By contrast, in spite of this newsroom automation, there is little dedicated digital support for non-science journalists to write about science. One exception is a new breed of digital tool that summarizes academic papers for non-scientific audiences [52]. For example, *Scholarcy* automatically reads research articles, reports and book chapters and breaks them down into bite-sized sections for users to assess the relevance of quickly [44]. Another new breed is the digital content verification tools that check scientific facts. For example, *SciCheck* is a feature of *FactCheck.org* that focuses exclusively on false and misleading scientific claims that are made by partisans to influence public policy [15]. Although useful, these breeds of tool, on their own, are unlikely to enable journalists to write and communicate stories about science to non-specialist audiences more effectively.

Few studies to inform the design of bespoke digital support for journalists to write better stories have been reported. Some of the exceptions were the design implications for future tools to discover local news information sources reported in [16], and the *Maater* system that corrected news misinformation using high-ranking crowd-sourced entries [29]. To work around the lack of available digital tools, some journalists have adopted general-purpose ones such as *import.io* and *www.social-searcher.com* that keyword-search multiple social media channels but not news information sources, and present comparative results. Other digital journalism tools have implemented artificial intelligence techniques. For example, the *Alchemy API* was developed to support journalists to make sense of unstructured natural language data and generate human insights using text analysis and visualization mechanisms. Likewise, the *NewsReader* tool implemented text analysis and artificial intelligence mechanisms to build structured event indexes of large volumes of financial and economic data for decision making from news content [36]. More recently, the *INJECT* tool implements creative search algorithms to discover content that it presents to journalists to use to discover and develop new angles on stories [31]. Newsroom studies demonstrated the *INJECT* tool's effectiveness [32]. Moreover, *INJECT* was implemented as a plug-in sidebar to existing text editors, to avoid the need to run yet another free-standing tool, and hence increase the likelihood of *INJECT's* uptake in newsrooms.

In this paper we build on ideas from some of these existing tools to design new and bespoke digital support for journalists to discover content for writing about science-related topics more effectively. We report the design of a new digital prototype called *INQUEST*. The participatory process to design *INQUEST* included engagement with both experienced science communicators and journalists not specialized in science.

4 The Participatory Design Process

The process sought the participation of experienced science journalists and communicators to provide domain expertise about science journalism challenges and good practices. It also sought the participation of other journalists who did not specialize in science journalism to provide the requirements for and feedback on the *INQUEST* prototype. The experienced science journalists and communicators were interviewed to refine the design team's understanding of the challenges facing science journalism and to discover good practices that the tool could encourage and support. The non-specialist journalists provided feedback on a first version of the prototype during 3 workshops. This feedback was used to design a more complete digital version of the *INQUEST* prototype. The outcomes from each stage of the participatory design process are reported.

4.1 Science journalism challenges and good practices

To collect domain expertise about science journalism challenges and good practices, the design team held semi-structured interviews with 18 experts – people with a track record as science journalists and in equivalent roles from 6 European countries – the UK, Ireland, Estonia, Norway, Italy and Germany. These experts comprised 11 science journalists in broadcast and print, 2 media consultants specializing in science, a freelance science communicator, a science editor, a science magazine editor, a science press officer and a science journalism academic. The interviews lasted between 25 and 1h16 minutes. During each interview, one member of the design team asked questions about the challenges facing science journalism, good practices for reporting it, the training available, preferred digital information sources, and emerging opportunities for science journalism. The full interview results are available at [35]. The results summarized in this paper draw on answers to questions asked about the challenges, good practices and digital information sources.

Our analysis of the interview transcripts led to the emergence of 4 key themes: 1) a lack of time and other resources to report science journalism; 2) the diverse digital information sources of value in science journalism; 3) the different audiences for science journalism, and; 4) the need for strategies to explain science to audiences. Each theme is reported with interview quotes in turn.

4.1.1 Lack of time and other resources.

The first theme was the challenge posed by the lack of time and other resources to write about science-related topics, even for experienced journalists with expertise in science. The lack of budget and time were reported by many: "*As an individual journalist within that unit, producing science content, the challenges are funding. Because everybody's being squeezed. That's actually a really significant issue actually*." (IV3), "*progressive reduction of time and money to pursue stories so that you can't cover simpler often too simple stories*" (IV15), "*Well the main challenge I face now is the fact that there are only 5 reporters and 2 political writers, so we're massively understaffed, so I have to cover science environment and to a certain extent health*" (IV8), and "*there's a definite lack of budget earmarked for science journalism in most of the mainstream media*" (IV17). The challenge was put into context by changes in news journalism, e.g. "*the other is a lack of time. Journalism became faster and faster and faster these days*." (IV10). It was compounded by growing workloads: "*..the treadmill of science press releases coming out from the big journals and everything else that it's really very, very difficult to do enterprising or investigative stories. You're just making sure you've got the big ones covered.*" (IV4). It led some of the experts to report the need for more resource, e.g.: "*yes* *we could we should have more journalists, who also are able to write science or write about science*" (IV5) and "*I think it's about editors who are empowered with the ability to change things to give science journalists more time or to involve them in the process earlier on*" (IV7). However, none of the experts reported that these resources had been or were expected to be forthcoming in their organizations.

Some of the experts also reported lacking the necessary expertise to interpret science, e.g.: "*the main challenge is that most journalists, unless they studied science at A level or at a higher level like university, really don't have a deep knowledge of basic science*" (IV1), and "*Firstly is um accuracy. This is a really complex…they tend to be quite complex stories, and very difficult to get the facts exactly right around the science*" (IV11).

In conclusion, interviewee responses revealed that even experienced science journalists frequently lacked the time needed to research and develop stories on science-related topics. Some also lacked the expertise needed to interpret complex science-based stories. Design implications for *INQUEST* inferred by the authors included the need to support journalists to work more efficiently, perhaps through the increased automation of some of their tasks.

4.1.2 Diverse digital information sources.

The second theme was the diversity of the digital information sources used to discover and learn about science stories in the time available to the experts. During each interview, the term *source* was used in its traditional sense in journalism, i.e. the origin of information used by journalists to develop ideas for new stories. The interviews revealed that no single type of digital source was used by more than half of the experts. Instead, the experts drew on the range of different types of source summarized in Table 1.

Table 1. Different types of digital information source mentioned by the experts as used regularly as the starting point for the development of science-related stories

Digital information Source	Description	Experts
Papers in science magazines and journals	Both online and hardcopy. Many journalists have negotiated journal access	7
EurekAlert!	Digital news distribution platform operated by the AAAS	6
Scientists on Twitter	Scientists promoting their work	4
Non-digital human actors	Policy directors, press officers, professionals, friends	4
Direct databases	PubMed, Scopus Scholar, Web of Science, EBSCO	2
University perspectives	Updates on institution activities	2
General news sources	Wider sources, e.g. New York Times, Guardian, BBC News	2
Google Alert/Scholar	Academic papers search engine	2
Google Search	General web search engine	2
Pre-print server papers	University-published papers	1
Few selected bloggers	Thoughts leaders	1

Less than half of the experts reported accessing science journals and magazines directly, in order to source their stories. Of those that did, several reported accessing leading journals and magazines such as *Science* and *Nature*, e.g.: "*Couple of sources, … the science magazines, of course, from Nature to Science Story Life or whatever*" (IV13) and "*Absolutely everything and everywhere. I mean I read Science and Nature, in hard copy. And I read the hard copy, because daily journalists look at the press releases, they get the emails of the press releases, of the papers that are important*" (IV8). Others had negotiated access to papers in more specialist journals, e.g. "*I do, because a lot of these journals, the publishers have started giving journalists blanket access, there are some journals, they will give you access if you email the press office and tell them which article you want and they'll send it to you by pdf*" (IV11). Another reported accessing pre-prints on university servers: "*You know nowadays we are looking at pre-print servers, that's where a lot of our stories are coming from… now there's a massive movement in the biological community to also put their papers on pre-print servers, so our journalists are looking at pre-print servers for stories because that's where they can discover you know big findings before they've even been peer-reviewed*" (IV4). However, the risks associated with pre-print papers were also recognized: "*So that's another conversation about how you do good science journalism around a pre-print paper which hasn't been peer reviewed yet. You have to have a kind of extra level of caution*" (IV4). Finally, some of the experts also accessed reports produced by recognized international bodies such as the *IPCC*, e.g. "*maybe the IPCC or other things for climate change they look at these reports and for overviews*" (IV10).

By contrast, the other 11 experts did not report using science journals as sources for their science-related stories. Multiple reasons were reported. Experts IV2 and IV3 depended instead on alert services such as *EurekAlert*!, while IV3 also relied on the alert services of major universities, and IV12 used tips and information provided directly by scientists.

Overall, 6 of the experts reported use of the AAAS's *EurekAlert!* service, as part of the suite of alerts available, e.g.: *"I'm on all the alerts. EurekAlert! I use a lot, yes I'm on all the alert sites for all the main publications*" (IV3). Other services reported by one of the experts were *Giga Alert*, *SuperDesk* and *NewsWhip*. However, other experts reported limitations with these services for writing about science, e.g. "*Yeah, I get EurekAlert!, but again everybody gets them, so they're of limited use to me*" (IV11), "*so I think they all have EurekAlert! they'll all have access to EurekAlert!…*" (IV2), and "*I used to but then it just overwhelmed me*" (IV18).

Four of the experts followed and used the tweets of high-profile scientists to remain up-to-date, e.g.: "*Twitter obviously for just staying up to date. Scientists use Twitter a lot*" (IV18), "*I used to get quite a lot of information through there. I think it's a really good kind of barometer of what's going on in the world. It can be really useful in that sense*" (IV11), and "*I use Twitter a lot. Not necessarily to find scientific papers but just to check out what people are talking about. Current debate in scientific communities in the areas that I cover*" (IV18). Another reported: "*It's a good place to get stories I think – and also to reach out to people, because you can get hold of people quite quickly on Twitter, if you want to interview them*" (IV11).

Only 2 of the experts reported using non-science sources such as news web-sites and newsletters to source their science-related stories: "*I get my everyday news, I try to get as broader range as possible, but mainly the New York Times, the Guardian and the BBC website*" (IV11) and "*it's more convenient for me to choose stranger sources so if I have to write original stories like in this case [points to his book]*" (IV9), and "*So I have newsletters coming from I don't know how many different places, from everywhere*" (IV18). Likewise, only 2 experts mentioned using general search engines such as Google to discover information with which to source science-related stories. And there was caution about press releases and PR outcomes, e.g. "*I never use press releases*" (IV11) and "*I ignore them 90 per cent of the time…. I don't trust them. I have seen so much greenwash*" (IV13).

In spite of the question's focus on digital information sources, another 4 experts also reported talking directly to people in roles such as press officers, science professionals and policy directors to discover information with which to source stories, e.g. "*some tips and from scientists from politicians*" (IV12), "*Yeah and very often it's by word of mouth. So I have a lot of contacts with a lot of people they will send me stuff*" (IV11), and "*I take [leading policy director] out every six months and say what's coming up what's coming up and try and build a pattern of features for the months ahead and in between that when stories break we will cover them as and when they come out*" (IV8). These reports indicated that not all valued sources are digital.

In conclusion, the interviews revealed that most science journalists did not report using journal articles as a primary source for developing their stories, and none reported using summarizer tools such as *Scholarcy* [44]. Rather, most used more diverse sources including science alerts, scientists' tweets, science newsletters, and general news to develop ideas for stories. Some of the science journalists also stressed the need to interact directly with people to discover new stories. Furthermore, responses to other questions asked during the 18 interviews but not analyzed in this paper revealed that many sought to talk directly to scientists in order to develop elements of their stories. These findings have implications for the design of *INQUEST*, and the types and range of information that could be retrieved as sources that journalists could use to develop new stories about science-related topics.

4.1.3 Audiences for science journalism.

The third theme that emerged from the interviews was the need to think about more specific audiences for science journalism. One reported the need for clear audience identification to generate directed content, for example: "*Are they actually reading reputable science journalism in say a newspaper like The New York Times that covers stories very well or a specialist science journal or are they just sort of looking at some video on YouTube or picking up something from their Twitter thread or you know if you're a young mother with children under 2 are they going onto Mumsnet* (a popular website for parents) *to get their information?*" (IV1). A radio journalist reported how her content was adapted to younger audiences: "*Yes, we've really tried, we've really changed the way we make programmes to try to appeal to different groups of people.... And we're obviously…trying to attract a younger audience…. So, I think it's a really, it's really educational, but without appearing to be educational. So, I think ways like that. Podcasts. There's lots of podcasts that we're doing in science. Trying to do it in different ways, different lengths, different lengths of programmes, shorter…. Yes, trying to make it more chatty, younger people, younger presenters, not so formal… Much more conversational, discursive*." (IV3). Another reported that social media had led to different types of content to align to different science journalism audiences: "*You know much more focus now on just meeting readers where they are so focus on social media, you know just, not necessarily expecting them to come to our site but just giving them the news whether it's on Facebook or Twitter, so newsletters is a big conversation and we've got a really successful um, newsletter that we started a year or two ago and that's been a really high priority actually for our team um, and its proving really popular, again no expectation that you'll actually click on anything in it, it's just there its getting you to know [our magazine] and science journalism.*" (IV4).

Overall, fewer of the experts reported a need to think about specific science journalism audiences, but those that did reported using different content, styles and channels. These results were consistent with results from studies that revealed audiences, excluded from, disengaged with or only moderately interested in science news (e.g. [4] [12] [43]). They also had implications for the design of *INQUEST*, and the audience segment information that could direct journalists to write about science-related topics for those audience segments.

4.1.4 Effective explanation.

The fourth theme that emerged from the interviews was the need to explain science more effectively. During the interviews, most reported the need to explain science and its relevance to readers, for example "*I see my job as explaining a bit more than say a political editor would*" (IV8) and "*but it's not only storytelling you have also to explain things to put things in context and so on*" (IV10). Stories could be judged by their explanations of the science, e.g. "*Is it interesting? Is it explained in a way that, how can we explain it*? (IV3) and "*There is an element of science, there is an element of explaining these things*" (IV6). Some of the experts also revealed different explanation strategies, e.g., presenting the background: "*sometimes when a news story gets so big, it will be sort of producers that call us up and we will try and help and scientists are really willing to sort of explain the background*" (IV2) and context: "*research about climate change while we do cover those, we tried to explain how it also concerns Estonia*" (IV5). Again, the findings had implications for design discussions to be made about *INQUEST*, and offered new guidance in the form of strategies to support journalists to explain science and its relevance to their audiences.

4.1.5 Implications for designing the *INQUEST* prototype.

The results from the 18 interviews were analyzed to inform decisions made about the design of *INQUEST* to support journalists to write about science-related topics. In order to overcome the challenge of lack of time and utilize the diverse digital information sources used by experts, the design team decided to automate some of the tasks that experienced science journalists regularly undertake. Therefore, *INQUEST* was developed to discover information already published in sources as diverse as journals, magazines, science alerts, scientists' tweets, and general news sources that could act as triggers to journalists to write new science-related stories, and present this information to journalists in standard forms in one place, for quick access. To support journalists to write for audiences less engaged in science, the team decided to design new guidance for writing for these audiences. *INQUEST* was developed to present personas for different audience segments, to provide information and guidance to the journalists during the writing process. And to provide effective explanations of science and its relevance, the team decided to operationalise an existing theory of narrative in guidelines that *INQUEST* presents to journalists to explain the science in different ways.

The next section reports the development of these features to support journalists writing about 3 key topics that were a focus for the first *INQUEST* prototype – the climate crisis, vaccine denial and the impact of artificial intelligence on the workplace.

4.2 Content for effective science communication

The science journalism and communication experts reported using diverse sources of digital information for developing new stories about science-related topics, each with advantages and disadvantages. Therefore, to offset the disadvantages associated with each single type of source, design decisions were made to develop the *INQUEST* prototype to discover information from multiple source types automatically, and to present this content to journalists who are writing new stories.

4.2.1 Published science content.

Some of the experts reported using scientific papers published in peer-reviewed journals to source and develop new stories. Moreover, they used prestigious journals as proxies for high quality science reported in the papers. Therefore, the *INQUEST* prototype was developed to retrieve and manipulate information from scientific papers that were published in prestigious journals related to specific topics from the climate crisis, vaccine denial, and the impact on artificial intelligence on the workplace. To determine these journal titles, the design team consulted experienced scientists and science journalists in each of the challenge areas, and identified a first set of 45 journals for the tool to retrieve information automatically from. These titles included *Nature Climate Change*, *Global Environmental Change* and *Global and Planetary Change* (for the climate crisis), the *New England Journal of Medicine*, *JAMA Pediatrics* and *British Medical Journal* (for vaccine denial) and the *Foundations and Trends in Machine Learning*, *IEEE Transactions on Pattern Analysis and Machine Learning* and *IEEE Transactions on Neural Networks and Learning Systems* (for artificial intelligence). An example of one paper that the tool might discover when writing a story about sea-level rises and the medieval city of Venice, published in *Climate Dynamics*, is shown on the left side of Figure 1.

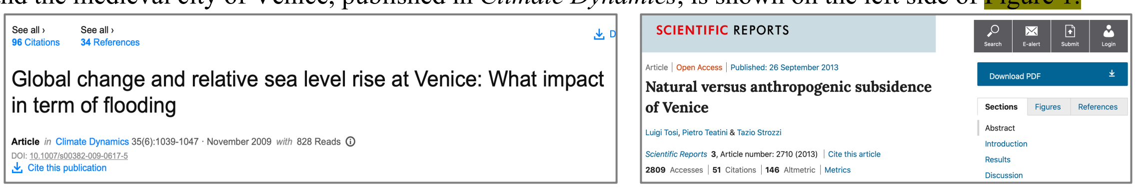

Figure 1: Titles of retrieved peer-reviewed publication related to sea-level rises in Venice, published in *Climate Dynamics, and* article related to sea-level rises in Venice, published in *Nature*.

The experts also reported using publications in prestigious science magazines. Therefore, the prototype was developed also to retrieve and manipulate information from articles published in prestigious science magazines. To determine the magazine titles, the design team consulted the same experienced scientists and science journalists, and identified a first set of 7 magazines that the tool retrieves information from automatically. These titles included *Science*, *New Scientist* and *Scientific American,* all of which publish articles such as shown on the right side of Figure 1. Both sets of peer-reviewed journals and scientific magazines could be easily extended with more expert input.

The experts also identified scientific institutions that produced reports to use during science communication such as the *European Space Agency* and *Intergovernmental Panel on Climate Change*, so the prototype was developed to retrieve and manipulate information from these reports and outputs.

4.2.2 Published news content.

Some of the experts reported using content published in newspapers as sources for stories. Therefore, the *INQUEST* prototype was developed also to retrieve and manipulate information from newspaper sources. Tried-and-tested software services already implemented in the *INJECT* digital tool to support journalists [31] reported in more detail later in Section 6.3 were invoked in the *INQUEST* prototype. These services provided access to news stories written each day in 380 titles in 6 European languages [31]. An example of such a story published by *CBS News* is shown on the left side of Figure 2.

4.2.3 Science alert services.

Some of the experts also reported using science news alert services to be valuable source for new stories, so the *INQUEST* prototype was also designed also to retrieve information related to specific topics from alerts published by 2 services used by many science journalists – *EurekAlert*! and *AlphaGalileo*. An example of an alert is shown on the right side of Figure 2.

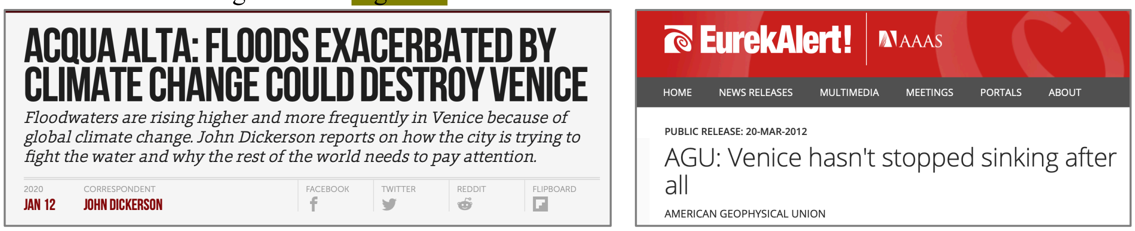

Figure 2: Title of news article related to sea-level rises in Venice, published by CBS News, and EurekAlert service alert on sea-level rises and Venice.

4.2.4 Scientist comments on social media.

Moreover, some of the experts also reported using the tweets of high-profile scientists to remain up-to-date with developments in science. Therefore, a design decision was made to develop the *INQUEST* prototype to retrieve information related to specific topics automatically from tweets posted by high-profile scientists and their research labs. Using source names identified by our experienced science journalists, the tool was set up to retrieve Twitter content including from 30 leading research teams and 170 leading scientists researching climate change, and 20 research teams and 80 leading scientists researching vaccines. Equivalent teams and scientists working in artificial intelligence were planned to be added to subsequent versions of the prototype.

4.2.5 Science audience personas.

Some of the experts reported writing for specific science journalism audiences. Therefore, the design team took inspiration from user personas in interaction design (e.g. [37]), and made a design decision to develop a set of new audience personas that represent a broader range of readers, their behaviours and their attitudes towards science that journalists believe can be current and future audiences. The *INQUEST* prototype was developed to retrieve these personas and present them automatically to journalists when writing about science-related topics.

A literature search revealed no existing audience personas for science journalism in the public domain. Therefore, the design team examined the small canon of existing research to determine whether populations could be divided into segments with different perceptions of science. Schafer et al. [43] applied latent class analysis to survey data from audiences in Switzerland to propose 4 important segments: *sciencephiles* with strong interest for science, extensive knowledge and belief in its potential; the *critically interested*, also with strong support for science but with less trust in it; *passive supporters* with moderate levels of interest, trust, and knowledge; and *disengaged* people who are not interested in science, do not know much about it and harbor critical views toward it. Similar segments were identified in [5] for science audiences in the United States. Furthermore, Dawson's ethnographic research [12] explored those most at risk from exclusion from science communication in low-income minority ethnic backgrounds, and argued that exclusion could be understood in terms of cultural imperialism (most scientists are white and middle class) and powerlessness (a sense that minorities are ignored by authorities).

Using these reported findings, the design team developed a first set of 8 science audience personas based on the *sciencephile* (1 persona) *critically interested* (1) *passive supporters* (2) and *disengaged* (4) audience segments in [43], and specialized them to describe excluded audiences from the ethnic minorities and with lower incomes. Each persona was developed to have a name, background, interests and activities encountered in most EU states, to enable their use by journalists in different EU countries. Figure 3 reports the first version of the designed *Michelle* persona. *Michelle* was designed to describe someone *disengaged* from science, i.e.

someone moderately in favor of basic research and public funding, but who still perceives science negatively [38]. She has low levels of education and large personal and professional distances to science, which translates into low motivation to engage and few contacts with it [43].

Michelle is a 45-year-old woman who runs a hairdressing business from the suburban home that she shared with her husband and teenage children. She left school at 16 to train as a hairdresser. Although she is intellectually curious her political views remain conservative, and she normally votes for centre-right parties. Her main sources of information are daily newspapers, Sky News, local radio and Facebook, and her large network of clients with whom she talks every day. Michelle has some interest in science that can impact on her health and that of her family, but no interest in science that does not have this impact. She thinks of science as limited to medical science, and does not perceive science to be relevant to other aspects of her life. She reads most of her information about science, irregularly, from health sections of the newspaper and from Facebook. She does not read science books or other publications. Her world outlook is a distrust of many professions (including science and journalism,) and likes to talk with friends and clients about news stories that demonstrate the limits of their knowledge of these professions. Michelle and her friends often question the trustworthiness of science that they read or hear about. However, living in a big city, she likes to exploit its culture, and visits its museums, galleries and botanical gardens from time to time.

Figure 3: Textual description of the first version of the *Michelle* persona, who is disengaged from science.

Another 7 similar science audience personas were designed and described in text form with equivalent information to similar levels of detail, for evaluation as part of the first *INQUEST* prototype.

4.2.6 Explanation support.

In response to the expert reports that explaining science was important, the design team investigated different theories that might support more effective explanation with different strategies. One was *Rhetorical Structure Theory* (RST) [34]. RST describes the organization of a written narrative as relations that hold between the parts of that narrative. It explains coherence by postulating a hierarchical, connected structure of texts. This structure is understood using predefined types of rhetorical relations between texts – relation types such as *background*, *description*, *circumstance* and *cause*. Because journalists writing about science from different sources are seeking to develop stories that are connected and coherent, the design team judged the RST rhetorical relation types as a valid start point for designing explanation sparks for science journalism. In the first version of the *INQUEST* prototype, explanation sparks were designed for 19 rhetorical relationship types. Each spark was designed to direct the journalist, and in particular less experienced ones, to think about new ways of explaining more entities extracted from existing papers, articles, stories and news alerts. For example, for the entity *measles vaccine*, two sparks directed the journalist to *think about describing* the causes for the measles vaccine to your audience and *think about incorporating the purpose of the measles vaccine if it is relevant to your audience*. The full first set of the designed explanation sparks is reported in Table 2.

Table 2. Some of the parameterized explanation sparks designed for the first *INQUEST* prototype. When presented to journalists in the prototype, each spark was designed to associate an entity extracted from the current paper, article or story with one or more audience personas already selected by the journalist

Think about different contexts of [entity] that might interest [your audience]
Think about how science offers different solutions to [entity] that might interest [your audience]
Think about elaborating on examples of [entity] that [your audience] might want to know about
Think about describing what [your audience] want to know about [entity] in their language
Think about the background of [entity] to offer story angles to [your audience]
Think about how [entity] motivates others, as part of a story for [your audience]

5 A First Prototype: Journalist feedback

A first prototype of *INQUEST* was developed to collect journalist feedback on key features and types of information content described in the previous section. This prototype was designed to be used in the first discovery stage of story development that involves the activities and techniques involved in fixing on a reporting idea or focus, formulating a reporting strategy, and seeking relevant information. [49]. To support this discovery phase, published science and news content were presented digitally using functions implemented in the new prototype. For each user request, the prototype presented up to 20 papers, articles and stories retrieved automatically from over 17 million news stories published over the previous 2 years in the 380 news publications in 6 European languages, over 12,000 peer-reviewed papers in the 45 listed journal titles, and from over 400 articles published in 7 listed science magazine titles published over the previous 12 months. Each set was retrieved automatically by creative search algorithms implemented in the existing *INJECT* tool [31] and presented in both a text editor sidebar and a web application, as shown in Figure 4. For each paper, article and story, the prototype displayed the title, publication date, where it was published, the first 20 words and one image taken from the paper or article, and a word cloud of frequent terms from each journal and/or article. By contrast, the first version of the designed audience personas and explanation sparks had not been implemented in the functional prototype, and were presented to the journalists on separate sheets of paper, overlaid onto or presented next to the digital content, see also Figure 4.

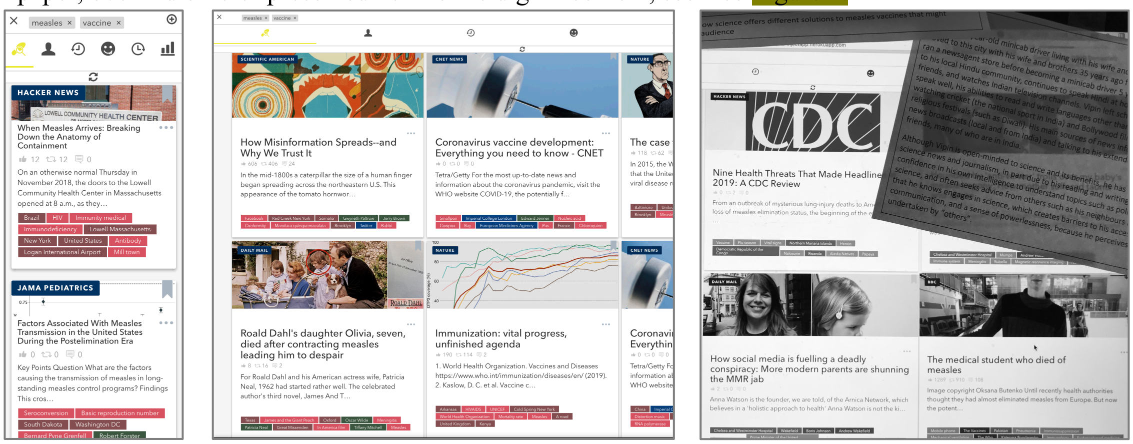

Figure 4: Mixed digital and paper content in the *INQUEST* first prototype, from left to right: the text editor sidebar view, the web application view, and the mixed digital and paper content presented to journalists.

Three workshops were held with users for whom *INQUEST* was being developed – journalists without specific science expertise and/or science journalism training but still writing about science-related stories. The first workshop was with 3 experienced Italian journalists – 2 worked for a local television channel and reported science-related stories in news broadcasts, and 1 was a freelancer who occasionally accepted commissions to write about science-related topics. The second workshop was with 2 journalists based in the UK – a freelance journalist with some experience of writing science stories, and an inexperienced journalist studying for a Masters in Interactive Journalism. The third workshop was held with 4 working but inexperienced journalists who were studying for Masters degrees in Journalism and Interactive Journalism. Only 1 of these 4 had a background in science, in the form of a Bachelor Degree. During each workshop, a member of the design team walked the journalists through the prototype's different features and information content, and asked them to comment on the value and implementation of each type, and changes to make.

Overall, the journalists in the 3 workshops were positive about all of the presented content types. Each was reported to have potential value to a journalist discovering themes to write about science-related stories. The text editor sidebar design was also a popular means of presenting the content to journalists writing stories.

However, the journalists also asked for changes to the content and features for presenting it, and for one new type of information content to be added. One of the changes was a feature to order and filter papers and articles by the type of source (e.g. by *science magazines*), to manage the volume of information retrieved by the prototype. Another was to have more immediate access to more word clouds, in order to access simple visual summaries quickly. Some of the journalists also asked for shorter summaries of the audience personas, because the two-paragraph descriptions shown in Figure 3 were too long to browse and understand when developing new stories. Some of the journalists also asked for more directed guidance about how to write stories for the different audience personas.

The new type of information content that some of the journalists requested was a set of metaphors – everyday objects and situations familiar to most non-specialist audiences similar to scientific challenges and theories

– shown to communicate science effectively to audiences. In particular, the 2 Italian broadcast journalists reported that their news reports often had less than 2 minutes to communicate a science-related story to a television audience, and often sought familiar metaphors to communicate the topic quickly. All 3 of the journalists in that first workshop agreed that a set of tried-and-tested science communication metaphors could support them to discover and think more about metaphors to use to communicate different science disciplines.

6 A More Complete Digital *INQUEST* Prototype

Based on the feedback from the workshops, the design team developed a first full version of the *INQUEST* prototype that incorporated all of the requested changes and the new set of science communication metaphors. The prototype displayed information of different types to journalists using an interactive sidebar based on the design of the *INJECT* tool sidebar. Information presented in this sidebar was retrieved automatically from papers from all of the reported types of digital source. The implementation of each of these key features is summarized in the next sections.

6.1 The *INQUEST* sidebar

The *INQUEST* interactive sidebar on the right side of the text editor was based on the *Google Docs* Add-on sidebar with a fixed width of 300px. To be usable within this limited width, the sidebar was implemented with mouse hover-boxes to present information content such as the explanation sparks using pop-up text boxes quickly in context. Different instances of the designed sidebar use are depicted in Figure 6.

6.2 The *INQUEST* information cards and explanation sparks

Each retrieved journal paper, magazine article and news article were presented in the sidebar using a separate information card that presented the title, publication date, where it was published, the first 20 words and one image taken from the paper or article. To present structured information about places, things, people and organizations that journalists might write about, each card presented up to 10 entities extracted automatically from each retrieved paper/article in colored rectangles, as described in Section 6.3. When the journalist placed the cursor over each entity or the article title, *INQUEST* presented a pop-up explanation spark generated for that entity or title to encourage the journalist to think about new ways to explain the entity to the intended audience. Implementation of these information cards and explanation sparks are also depicted in Figure 5.

6.3 The retrieval and entity extraction algorithms

The *INQUEST* prototype built on the search algorithms and tools implemented in the *INJECT* tool [31]. Retrieval was in two parts – prior semantic indexing of content and content index searches in real-time in response to journalist requests. The *INJECT* Presser service already fetched verified news stories from over 1000 predefined RSS feeds published by 380 diverse news titles in 6 languages. These titles included broadsheet titles such as the *Guardian* and *New York Times* and tabloid newspapers such as the *Daily Mail* and *The Sun*. On a normal news day, it fetched about 15,000 stories. Stories from high-frequency feeds were fetched every 30 minutes, others every 12 hours. The prototype stored information about fetched stories in its creative news index, an external Elasticsearch cluster manipulated by its creative search algorithms. In March 2020, the Elasticsearch cluster held over 17million entries, with another 350,000 or so new entries being added each month. In the *INQUEST* prototype, the Presser service was extended to fetch the peer-reviewed journals, science magazine articles and scientific reports from the climate change, vaccine and AI specialist sources reported in section 4.2.

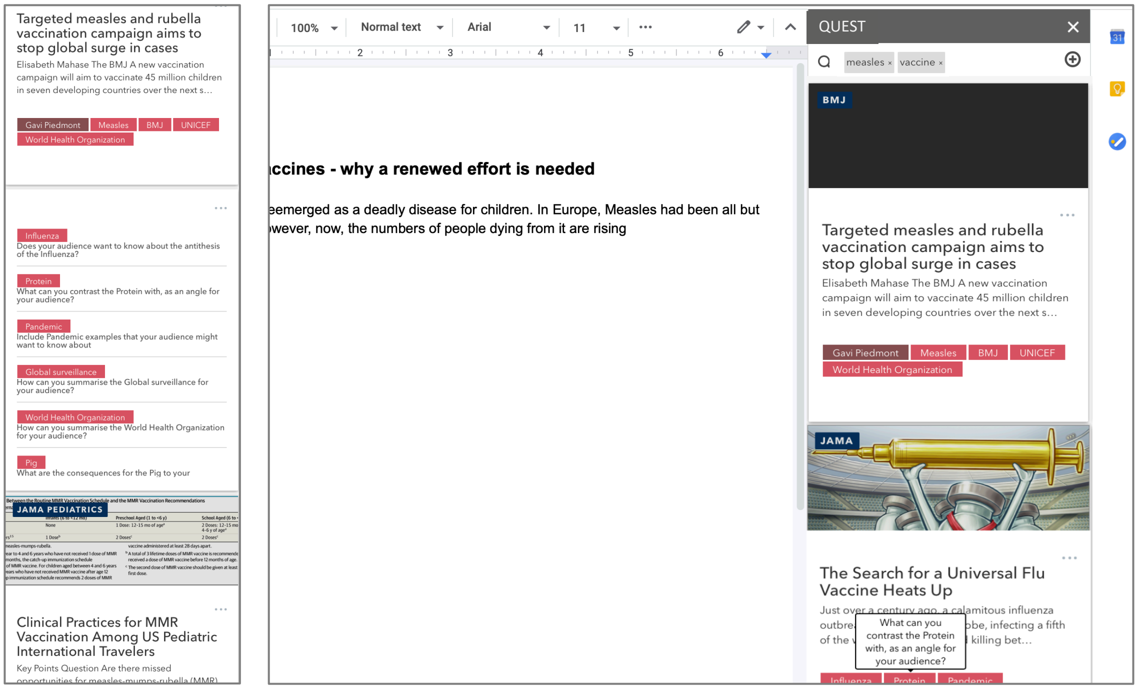

Figure 5: **The *INQUEST* sidebar in a Google Docs text editor, showing information cards and explanation sparks related to explaining protein in a new story about measles vaccines.**

Entities were extracted from the retrieved stories, and papers using established named entity extraction mechanisms such as *DBpedia Spotlight* [13] and *Polyglot* [38]. *Spotlight* annotated mentions of *DBpedia* resources using entity detection and disambiguation algorithms with adjustable precision and recall, while *Polyglot* implemented named entity extraction, speech tagging, sentiment analysis, morphological analysis, and transliteration. Automatic parser mechanisms also detected the reported nouns and verbs to index stories using common objects and actions. Combining these parsers and entity extraction mechanisms provided the *INQUEST* prototype with substantial semantic content about each paper, article, story and report.

6.4 The audience personas

New versions of the designed audience personas shown in Figure 3 were extended with 75-word precis and photographs to make each easier to understand quickly. Furthermore, to provide journalists with more directed guidance about how to write stories for the different personas, themes such as the reading level, social media uses, and interests were added as entities that journalists could interact with to create ideas about for readers in each segment. Eight such audience personas were implemented in the first full version of the *INQUEST* prototype, and 4 are shown in Figure 6. Journalists were able to read and select between the full descriptions of all 8 personas using a simple and accessible feature of the prototype available at all times.

6.5 The science communication metaphors

Metaphors are heuristic tools for science communication that enable non-scientists to learn knowledge that may be too complex or abstract to understand in its original form [53]. Well-known science metaphors include the *greenhouse effect* and *herd immunity*. Therefore, the design team undertook an extensive search of metaphors used to communicate science related to the climate crisis, vaccine use and AI in society. A first set of 18 metaphors with titles, images, and descriptions were implemented. Each metaphor also included simple guidelines to encourage journalists to think about its limits, because outdated metaphors can limit public understanding [53], and wrong language can re-enforce stereotypical thinking and political meaning [19]. Furthermore, to encourage journalists to think creatively about metaphor use, each included important topics represented as entities that journalists could interact with to explore guidance such as: *Will your* *audience understand this metaphor? Change it to something they are more familiar with*, and: *Think about including dramatic images of the metaphor in your story*. These features were included to support journalists to avoid the overuse of worn-out metaphors and to evolve new ones that better communicate their science-related stories. Presentation of 6 of the 18 metaphors and an example of the interactive support for creative thinking about the metaphors in the *INQUEST* prototype are also shown in Figure 6.

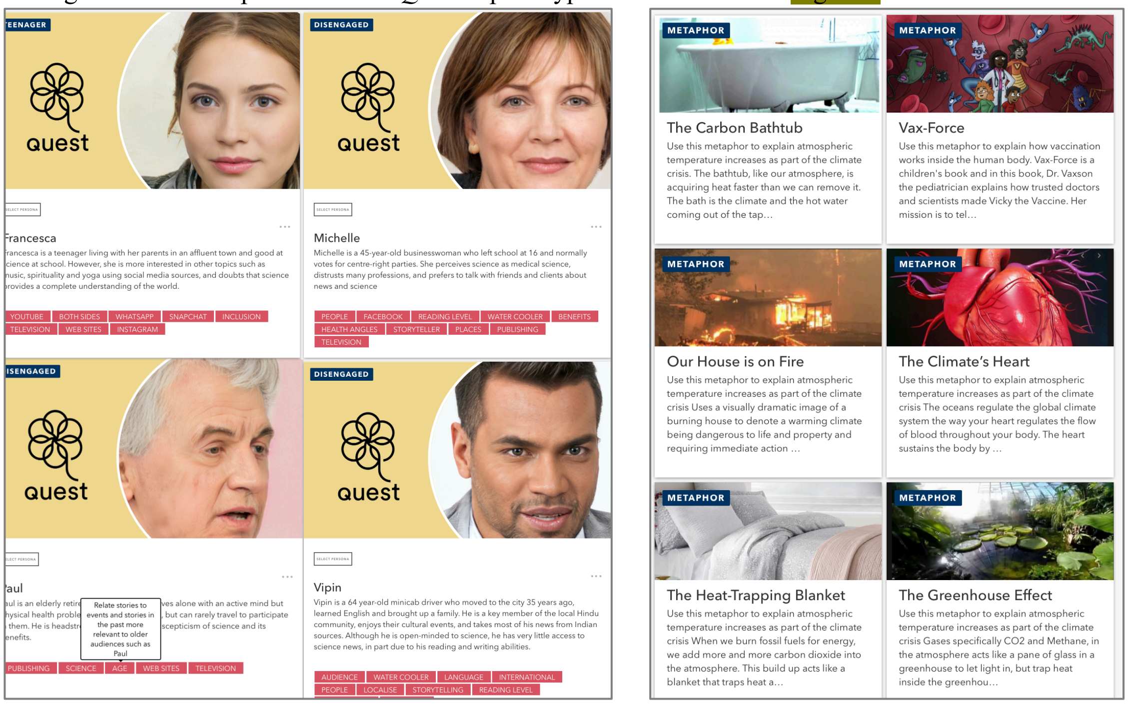

Figure 6: The *INQUEST* web application prototype displaying some of the audience personas, guidance about the *Paul* persona and people of similar age, and science communication metaphor content generated for it.

7 Discussion and Next Steps

Science journalism has the power to shape society by communicating science effectively so that people are informed when making democratic decisions (e.g. [2]). As a consequence, how we craft the new forms of digital technologies to support this science journalism will impact on both our democracies and our lives. The initial research reported in this paper revealed that most journalists lack the necessary resources and digital information to communicate science to more diverse audiences effectively. It also provided first evidence that this knowledge gap could be filled by digital implementation and augmentation of parts of some of the tasks that journalists under time pressures undertake when writing about science-related topics.

The research reported in this paper makes two potential contributions to science journalism research. The first is the identification and development of types and forms of content that digital technologies could present to journalists in new, more efficient ways that have the potential to augment the knowledge and skills of these journalists, based on the interviews with 18 science journalism and communication experts. The second is preliminary empirical evidence that journalists can accept the digital manipulation and presentation of this content to augment their knowledge when writing about science journalism. Indeed, presenting this content in the existing work tools of journalists, e.g. as an optional science journalism sidebar of text editors, appears to be important for this acceptance [21]. This second contribution also revealed new means of delivering empowering digital capabilities to journalists without risks of perceived over-automation of their work.

Prototypes such as *Science-blogger* [55] and tools such as *Scholarcy* [44], which summarize academic papers for non-scientific audiences [52], and tools such as *SciCheck* [15] that verify digital content verification to check scientific facts have received considerable recent attention in science journalism. However, the problems that these tools were developed to solve were reported only occasionally in the interviews with the science journalism and communication experts. Instead, the challenges identified by the 18 experts – lack of time, finding digital sources for stories in diverse information sources, writing for different audiences, and explaining science to these audiences – suggests the need for other forms of digital support. The identification of these alternative challenges reveals the value of our participatory design approach.

The *INQUEST* prototype presented in this paper is currently being improved. The existing science audience personas are being refined and new ones developed to describe more low-income and/or ethnic minority people identified to be more disengaged with science [12]. Further paper prototyping is being used to improve each persona's accuracy and value to journalists. The creative search algorithms are also being refined to return more blended mixes of scientific, news and other content that journalists will be able to use more directly in story identification and development. The set of science communication metaphors is being extended and redeveloped to be more interactive, to enable journalists to think more creatively about how to communicate science-related content to specific audiences. The user settings, not described in this paper, are being extended to enable individual journalists to be able to customize *INQUEST* prototype features and content to their needs.

Furthermore, the information content developed for use in the *INQUEST* prototype can seed other types of science journalism activities. For example, the extended set of science audience personas can be used in science journalism education and training courses. Likewise, the evolving set of science communication metaphors can be made available to journalists as a standalone booklet, toolkit or website, to encourage the widest possible use of the new content.

Of course, the participatory design process used to prototype *INQUEST* also raises questions about the validity of the research. For example, threats to external validity were conditions that limited our ability to generalize the results [56] – in this case the participatory design of one prototype that involved fewer than 30 journalists. However, the prototype's core capabilities were based on results collected from interviews with 18 science journalism and communication experts from 6 countries that required time and effort to negotiate and collect. Few if any equivalent alternative studies have been reported. The expert interviews were also subject to threats to internal validity of the evaluation [56]. One obvious risk was the possible underreporting of the use of information sources because of well-documented taken-for-granted knowledge and selective recall problems associated with verbal reports [24], with the consequence that more of the experts could have used more of the different types of digital information source. However, the subsequent design of the *INQUEST* prototype incorporated all of the reported source types, so this bias did not influence the design outcome. Another threat in the form of an influence that could have affected independent variables was potential design bias from the existing *INJECT* tool. That said, the design of *INJECT* had been informed by co-design with journalists in different newsrooms [31] and used successfully in newsrooms [32]. Therefore, we consider that this bias was acceptable during the development of a prototype, but will ensure that the next stages of *INQUEST* development are not influenced negatively by the *INJECT* tool design. More generally, the current *INQUEST* prototype manipulates written language rather than large datasets and/or visualisations of these datasets. Future versions will consider if and how support for data and information visualizations, perhaps from other products, can enhance journalist knowledge and capabilities.

This paper reports one of the first projects in which journalists participated directly to design new forms of interactive digital support for science journalism. The decision to design this support from the viewpoints of journalists and science journalism contrasts with recent empirical research that investigated communication barriers from the viewpoint of scientists [46]. It provides a useful starting point for further exploration, in a world in which the need for reliable scientific reporting to public audiences is more important than ever.

ACKNOWLEDGMENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824634.

REFERENCES

<bib id="bib1"><number>[1]</number>Matthew Ancona. 2017. *Post-Truth: The New War on Truth and How to Fight Back*. Ebury Press</bib>

<bib id="bib2"><number>[2]</number>Martin W. Angler. 2017. *Science Journalism: An Introduction*. Routledge.</bib>
<bib id="bib3"><number>[3]</number>James Ball. 2017. *Post Truth – How Bullshit conquered the World*. Biteback Publishing.</bib>
<bib id="bib4"><number>[4]</number>John C. Besley. 2018. Audiences for Science Communication in the United States. *Environmental Communication* 12, 8, 1005-1022, DOI: 10.1080/17524032.2018.1457067 </bib>
<bib id="bib5"><number>[5]</number>John C. Besley and Matthew Nisbet. 2011. How Scientists View the Public, the Media and the Political Process. *Public Understanding of Science* 22, 6, 644-659. DOI 10.1177/0963662511418743</bib>
<bib id="bib6"><number>[6]</number>Balázs Bodó (2019) Selling News to Audiences – A Qualitative Inquiry into the Emerging Logics of Algorithmic News Personalization in European Quality News Media. *Digital Journalism* 7(8), 1054-1075, DOI: 10.1080/21670811.2019.1624185</bib>
<bib id="bib7"><number>[7]</number>Massimiano Bucchi. 2013. Style in science communication. *Public Understanding of Science* 22, 8, 904–15. DOI 10.1177/0963662513498202</bib>
<bib id="bib8"><number>[8]</number>Sarah Castell, Anne Charlton, Michael Clemence, Nick Pettigrew, Sarah Pope, Anna Quigley, Jayesh Navin Shah and Tim Silman. 2014, *Public Attitudes to Science*, UK Department for Business, Innovation and Skills, accessed April 9, 2020. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/348830/bis-14-p111-public-attitudes-to-science-2014-main.pdf.</bib>
<bib id="bib9"><number>[9]</number>Mwenya Chimba and Jenny Kitzinger. 2010. Bimbo or Boffin? Women in Science: An Analysis of Media Representations and How Female Scientists Negotiate Cultural Contradictions. *Public Understanding of Science* 19, 5, 609–24. DOI: 10.1177/0963662508098580 </bib>
<bib id="bib10"><number>[10]</number>Evan Davies. 2017. *Post Truth: Why we have reached peak bullshit and what we can do about it*. Little Brown, Great Britain.</bib>
<bib id="bib11"><number>[11]</number>Nick Davies. 2009. *Flat Earth News*. Vintage Books, London.</bib>
<bib id="bib12"><number>[12]</number>Emily Dawson. 2018. Reimagining publics and (non) participation: Exploring exclusion from science communication through the experiences of low-income, minority ethnic groups. *Public Understanding of Science* 27, 7, 772-786. DOI: /10.1177/0963662517750072 </bib>
<bib id="bib13"><number>[13]</number>DBpedia Spotlight. 2017. https://github.com/dbpedia-spotlight/, accessed December 21, 2017.</bib>
<bib id="bib14"><number>[14]</number>Sharon Dunwoody. 2014. Science Journalism: Prospects in the Digital Age. In *Handbook of Public Communication of Science and Technology* (2nd ed.), Massimiano Bucchi and Brian Trench (editors), 27–39. Routledge, New York, NY.</bib>
<bib id="bib15"><number>[15]</number>FactCheck.org, https://www.factcheck.org/scicheck/. Accessed April 9, 2020.</bib>
<bib id="bib16"><number>[16]</number>Andrew Garbett, Rob Comber, Paul Egglestone, Maxine Glancy and Patrick Olivier. 2014. Finding "real people": trust and diversity in the interface between professional and citizen journalists, In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'14)*, ACM Press, New York, NY 3015-3024. DOI: 10.1145/2556288.2557114</bib>
<bib id="bib17"><number>[17]</number>Winifrid Goepfert. 2007. The strength of PR and the weakness of science journalism. In *Journalism, Science and Society*, Martin W. Bauer M and Massimiano Bucchi, M (editors). Routledge, New York, 215-226. DOI: 10.4324/9780203942314</bib>
<bib id="bib18"><number>[18]</number>Suzanne Goldenberg. 2012. *Leak exposes how Heartland Institute works to undermine climate science*. The Guardian. https://www.theguardian.com/environment/2012/feb/15/leak-exposes-heartland-institute-climate, accessed April 25, 2020.</bib>
<bib id="bib19"><number>[19]</number>Lars Guenther, Jenny Bischoff, Löwe, A., and Hanna Marzinkowski. 2017. Scientific evidence and science journalism: Analysing the representation of (un)certainty in German print and online media. *Journalism studies* 20(1), 40-59. DOI: 10.1080/1461670X.2017.1353432.</bib>
<bib id="bib20"><number>[20]</number>Anders Hansen. 2009. Science, Communication and Media. In *Investigating Science Communication in the Information Age*, Richard Holliman, Elizabeth Whitelegg, Eileen Scanlon, Sam Smidt, and Jeff Thomas (editors). 105–127. Oxford, Oxford University Press.</bib>

<bib id="bib21"><number>[21]</number>Joan M. Herbers 2007. Watch Your Language! Racially Loaded Metaphors in Scientific Research. *BioScience* 57, 2 (February 2007), 104–105. DOI: 10.1641/B570203</bib>
<bib id="bib22"><number>[22]</number>Maja Horst, Sarah R. Davies and Alan Irwin. 2016. Reframing Science Communication. *The Handbook of Science and Technology Studies* (4th ed), Clark A. Miller, Laurel Smith-Doerr and Ulrike Felt (editors), Cambridge, MIT Press.</bib>
<bib id="bib23"><number>[23]</number>Cherilyn Ireton and Julie Posetti (Editors). 2018. *Journalism, Fake News and Disinformation*. Handbook for Journalism Education and Training UNESCO Series on Journalism Education. https://en.unesco.org/sites/default/files/journalism_fake_news_disinformation_print_friendly_0.pdf</bib>
<bib id="bib24"><number>[24]</number>Daniel Kahneman, Paul Slovic and Amos Tversky. 1982. *Judgement under Uncertainty: Heuristics and Biases*. Cambridge University Press.</bib>
<bib id="bib25"><number>[25]</number>David Kaiser, John Durant, Thomas Levenson, Ben Wiehe, and Peter Linett. 2014. Report of Findings: September 2013 Workshop. MIT and Culture Kettle. www.cultureofscienceengagement.net </bib>
<bib id="bib26"><number>[26]</number>Silje Kristiansen, Mike S. Schäfer, and Sabine Lorencez. 2016. Science journalists in Switzerland: Results from a survey on professional goals, working conditions, and current changes. *Studies in Communication Sciences* 16(2), 132-140. DOI: 10.1016/j.scoms.2016.10.004</bib>
<bib id="bib27"><number>[27]</number>Trudie Lang and Peter Drobac. 2020. How journalists can help stop the spread of the coronavirus outbreak. Reuters. The Reuters Institute for the Study of Journalism https://reutersinstitute.politics.ox.ac.uk/risj-review/how-journalists-can-help-stop-spread-coronavirus-outbreak</bib>
<bib id="bib28"><number>[28]</number>Markus Lehmkuhl and Hans Peter Peters. 2016. Constructing (Un-)Certainty: An Exploration of Journalistic Decision-Making in the Reporting of Neuroscience. *Public Understanding of Science* 25, 8, 909-926. DOI: 10.1177/0963662516646047.</bib>
<bib id="bib29"><number>[29]</number>Raymond Liaw, Ari Zilnik, Mark Baldwin and Stephanie Butler. 2013. Maater: crowdsourcing to improve online journalism. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13*), ACM Press, New York, NY, 2549-2554. DOI: 10.1145/2468356.2468828</bib>
<bib id="bib30"><number>[30]</number>Tommy Carl-Gustav Linden. 2018. Algorithms for journalism: The future of news work. *The Journal of Media Innovation* 4(1), 60-76. DOI: 10.5617/jmi.v4i1.2420</bib>
<bib id="bib31"><number>[31]</number>Neil Maiden, George Brock, Konstantinos Zachos, Amanda Brown, Lars Nyre, Dimitris Apostolou and Jeremy Evans. 2018, Making the News: Digital Creativity Support for Journalists. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '18)*, ACM Press, New York, NY, Paper No 475. DOI: 10.1145/3173574.3174049</bib>
<bib id="bib32"><number>[32]</number>Neil Maiden, Konstantinos Zachos, Amanda Brown, Lars Nyre, Balder Holm, Aleksander Tonheim, Claus Hesseling and Andrea Wagemans. 2019. Evaluating the Use of Digital Creativity Support by Journalists in Newsrooms', In *Proceedings 2019 SIGCHI Conference on Creativity and Cognition (C&C19)*, ACM Press, New York, NY, 222–232. DOI: 10.1145/3325480.3325484</bib>
<bib id="bib33"><number>[33]</number>Henry Mance. 2016. *Britain has had enough of experts, says Gove*. Financial Times. https://www.ft.com/content/3be49734-29cb-11e6-83e4-abc22d5d108c, accessed April 25, 2020.</bib>
<bib id="bib34"><number>[34]</number>William C. Mann and Sandra A. Thompson. 1988. Rhetorical structure theory: toward a functional theory of text organization, Interdisciplinary *Journal for the Study of Discourse* 8, 3, 243–281. DOI: 10.1515/text.1.1988.8.3.243</bib>
<bib id="bib35"><number>[35]</number>Oliver Marsh. 2018. "Nah, musing is fine. You don't have to be 'doing science'": emotional and descriptive meaning-making in online non-professional conversations about science. PhD thesis, Department of Science and Technology Studies, University College London, London, UK.</bib>
<bib id="bib36"><number>[36]</number>Anne-Lyse Minard, Manuela Speranza, Eneko Agirre, Itziar Aldabe, Marieke van Erp, Bernando Magnini, German Rigau and Ruben Urizar. 2015. SemEval-2015 Task 4: Timeline: cross-document event ordering. In *Proceedings of the 9th International Workshop on Semantic Evaluation*, 778-786.</bib>

<bib id="bib37"><number>[37]</number>Lene Nielsen. 2013. Personas. In Encyclopaedia of Human-Computer Interaction (2nd ed), Mads Soegaard Mads and Rikke Friis Dam (editors). Aarhus, Denmark: The Interaction Design Foundation, 2013, http://www.interaction-design.org/encyclopedia/personas.html, accessed April 28, 2020.</bib>
<bib id="bib38"><number>[38]</number>Polyglot's documentation, 2017, http://polyglot.readthedocs.io, accessed December 21, 2017.</bib>
<bib id="bib39"><number>[39]</number>QUEST. 2020. *Summary Report: European Science Communication Today*. Deliverable D1.1, EU H2020-funded 824634 QUEST project.</bib>
<bib id="bib40"><number>[40]</number>Cecilia Rosen, Lars Guenther and Klara Froehlich. 2016. The question of newsworthiness: A cross-comparison among science journalists' selection criteria in Argentina, France, and Germany. *Science Communication* 38(3), 328-355. DOI: 10.1177/1075547016645585</bib>
<bib id="bib41"><number>[41]</number>Alan Rushbridger. 2018. *Breaking News: The Remaking of Journalism and Why It Matters Now*. Canongate.</bib>
<bib id="bib42"><number>[42]</number>Mike S. Schäfer. 2011. Sources, characteristics and effects of mass media communication on science: a review of the literature, current trends and areas for future research. *Sociology Compass* 5(6), 399-412. DOI: 10.1111/j.1751-9020.2011.00373.x</bib>
<bib id="bib43"><number>[43]</number>Mike S. Schäfer, Tobias Füchslin, Julia Metag, Silje Kristiansen and Adrian Rauchfleisch. 2018. The different audiences of science communication: A segmentation analysis of the Swiss population's perceptions of science and their information and media use patterns, *Public Understanding of Science* 27, 1, 836–856. DOI: 10.1177/0963662517752886</bib>
<bib id="bib44"><number>[44]</number>Scholarcy, https://www.scholarcy.com, accessed April 9, 2020.</bib>
<bib id="bib45"><number>[45]</number>Sophie Schünemann. 2013. Science Journalism. In Specialist Journalism. Barry Turner and Richard Orange (editors). Routledge, London, 134-146. DOI: 10.4324/9780203146644</bib>
<bib id="bib46"><number>[46]</number>C. Estelle Smith, Eduardo Nevarez and Haiyi Zhu. 2020. Disseminating Research News in HCI: Perceived Hazards, How-To's, and Opportunities for Innovation. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'20)*, ACM Press, New York, NY</bib>
<bib id="bib47"><number>[47]</number>Helle Sjøvaag. 2014. Homogenisation or Differentiation? The Effects of Consolidation in the Regional Newspaper Market. *Journalism Studies* 15, 5. 511-521. DOI: 10.1080/1461670X.2014.885275</bib>
<bib id="bib48"><number>[48]</number>Saniat Javid Sohrawardi, Sovantharith Seng, Akash Chintha, Bao Thai, Andrea Hickerson, Raymond Ptucha, and Matthew Wright. 2020. DeFaking Deepfakes: Understanding Journalists' Needs for Deepfake Detection. In *Proceedings of the Computation + Journalism 2020 Conference*. Northeastern University.</bib>
<bib id="bib49"><number>[49]</number>Ivor Shapiro. 2010. Evaluating Journalism. *Journalism Practice* 4(2), 143-163. DOI: 10.1080/17512780903306571</bib>
<bib id="bib50"><number>[50]</number>Jon Sopel. 2018. *From 'alternative facts' to rewriting history in Trump's White House*. BBC News. https://www.bbc.com/news/world-us-canada-44959300, accessed April 25, 2020.</bib>
<bib id="bib51"><number>[51]</number>Annika Summ and Anna-Maria Volpers. 2016. What's science? Where's science? Science journalism in German print media. *Public Understanding of Science* 25(7), 775-790. DOI: 10.1177/0963662515583419</bib>
<bib id="bib52"><number>[52]</number>Mico Tatalovic. 2018. AI writing bots are about to revolutionise science journalism: we must shape how this is done. *Journal of Science Communication* 17, 1. DOI: 10.22323/2.17010501</bib>
<bib id="bib53"><number>[53]</number>Cynthia Taylor and Bryan M. Dewsbury. 2018. On the Problem and Promise of Metaphor Use in Science and Science Communication, *J Microbiol Biol Educ* 19, 1. 46. DOI: 10.1128/jmbe.v19i1.1538</bib>
<bib id="bib54"><number>[54]</number>Peter Tolmie, Rob N Procter, Mark Rouncefield, Dave Randall, Christian Burger, Geraldine Wong Sak Hoi, Arkaitz Zubiaga and Maria Liakata. 2017. Supporting the use of user generated content in journalistic practice. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'17)*, ACM Press, New York, NY.</bib>
<bib id="bib55"><number>[55]</number>Raghuram Vadapalli, Bakhtiyar Syed. & Nishant Prabhu. 2018. Sci-Blogger: A Step Towards Automated Science Journalism. In *Proceedings 27th ACM International*

Conference on Information and Knowledge Management (CIKM'18). ACM Press, New York NY. 1787-1790.</bib>
<bib id="bib56"><number>[56]</number>Claes Wohlin, Per Runeson, Martin Host, Magnus C. Ohlsson., Bjorn Regnell and Anders Wesslen. 2000. *Experimentation in Software Engineering: An Introduction*. Kluwer Academic Publishers, Boston/Dordrecht/London.</bib>