Articles

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Threshold concepts in science journalism

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Abstract

Reporting of the COVID pandemic and the climate crisis has highlighted the importance of scientific literacy as a key skill for journalists. In the post-truth era where conspiracy theories and misinformation abound on social media, informed and accurate reporting has never been more important. The journey from news journalist to science journalist involves acquisition of specialist skills and knowledge, some of which is counterintuitive to the traditional practices of journalism.

Threshold concepts are transformative, troublesome

and difficult to grasp. They are conceptual gateways or portals in disciplines. They can cause students to become anxious and stuck but once mastered they are unlikely to be forgotten and can transform a student's view of the world.

Reflecting on teaching of a specialist science journalism module at two London universities, this paper will use action research to identify seven threshold concepts involved in the instructional journey from news journalist to science journalist:

- understanding of the scientific method;
- distinguishing the views of people with strong opinions from those with compelling scientific evidence;
- avoiding false balance;
- beware of the maverick and the miracle cure;
- correlation is not causation;
- chance event clusters;
- regression to the mean.

It is suggested that introducing these concepts into more general discourses in journalism education could illuminate and inform the reporting of science, health and the environment, broaden the education of journalism students and improve their employability.

Introduction

The COVID pandemic has highlighted the importance of scientific literacy as a key skill for journalists.

Since the pandemic began dominating global news agendas, news reporters have been required to get to grips with highly politicised stories often involving the interpretation of complex scientific and statistical analysis. Journalists face similar challenges reporting aspects of the climate crisis and other complex stories in the fields of science, health and technology. As misinformation and conspiracy theories circulate online and on social media, trusted reporting is at a premium.

The emergence of data journalism as a discipline has required journalism educators to integrate skills of statistical literacy into the curriculum. As Lewis, et al. (2020) suggest: 'journalists in a shrinking job market can no longer afford to let a fear of numbers restrict their career options'.

Teaching a science journalism module to journalism students involves promoting understanding of other troublesome concepts which are often counterintuitive to traditional practices of journalism. Without them, effective reporting of science can be confused and obscured (Nelkin, 1987).

At the heart of the understanding required is a clash of cultures between the journalist and the scientist. Science is a slow, patient, precise, careful, conservative, complicated process. Scientists are sticklers for detail; they write in scientific language and can take months or years before they publish research usually focussed on a tiny piece of a puzzle.

The news journalist is hungry for drama, conflict, human interest, quirky stories, breakthroughs and scares. News journalists work to daily deadlines, write in everyday language and are required to report the whole story at once. Pressure on journalists has been exacerbated by changing audience habits, declining attention spans and less interaction with long form journalism. Increasingly audiences consume news through online and mobile channels and social media (Angler, 2017).

By focussing on initial misunderstandings and subsequent understandings involved in teaching journalism students how to report science, this paper proposes seven threshold concepts in the journey from general journalist to science journalist. It is suggested that understanding of these concepts can inform and improve the reporting of science and help define the discipline of science journalism.

Literature review - the misunderstanding of science

Government research suggests most of the UK population believes it is important to know about science, yet most feel poorly informed and generally distrustful of media reporting. Research conducted before the COVID pandemic suggested people were increasingly accessing information about science online. Most still felt the media sensationalised science and politicians were too easily influenced by media reporting of emerging science such as robotics, artificial intelligence, genome editing, and micro-plastic pollution for example (Castell, et al., 2014; Department for Business, Energy and Industrial Strategy, 2020)

A common thread in discussion of media reporting of science involves the 'gulf of understanding' between communities of arts and sciences first identified more than sixty years ago by the novelist and chemist C.P Snow in his lecture and essay 'The Two Cultures'. In it he describes:

> *'Literary intellectuals at one pole—at the other scientists, and as the most representative, the physical scientists. Between the two a gulf of mutual incomprehension—sometimes (particularly among the young) hostility and dislike, but most of all lack of understanding. They have a curious distorted image of each other. Their attitudes are so different that, even on the level of emotion, they can't find much common ground' (Snow, 1963).*

'A crisis of trust' in society's relationship with science was highlighted in 2000 in a UK House of Lords Select Committee report which called for a sea change in favour of open and positive communication between the scientific community and the media (House of Lords Science and Technology Committee, 2000).

In the years that followed, the medical doctor and writer Ben Goldacre started his newspaper column focussing on pseudoscience and the misuse of science which coined the expression 'Bad Science'. His subsequent best-selling book suggested that at the root of the problem was a historic issue in which 'people who run the media are humanities graduates with little understanding of science who wear their ignorance as a badge of honour' (Goldacre, 2009).

Other critics have accused news media of not fully understanding the nature of scientific discourse; 'scientists who don't speak English and reporters who don't speak science and gatekeepers who are uncertain' (Fox, et al., 2010; Hartz & Chappell, 1997; Jones, 2011).

Following the House of Lords report, organisations such as sciencemediacentre.org and senseaboutscience.org were established to promote public understanding of science. Briefing notes they produce provide journalists with context around scientific stories in the news (Science Media Centre, 2021; Sense About Science , 2021).

More recently, a small number of textbooks on science journalism were published. Whilst they acknowledge the importance of statistical literacy, they focus for the most part on interviewing, writing and storytelling techniques (Angler, 2017; Blum, et al., 2006).

A decline in professional training for journalists has left media organisations relying on the higher education sector for a trained workforce, although only a small number offer specialised modules in science reporting (Fox, et al., 2010). Some US universities offer postgraduate qualifications specialising in science journalism, a number of British universities offer postgraduate qualifications in science communication, yet a search of the UCAS website in 2021 suggests that only one British university was offering a specialist course in science journalism.

The Horizon 2020 funded Quality and Effectiveness in Science and Technology communication project has proposed an outline curriculum for an MA in Science Journalism. Alongside traditional reporting skills it includes understanding of science, media and society, ethics, statistics and the methods scientists use to gather and publish data (Schofield & Franks, 2020).

What is less prominent in these discourses is attention to fundamental understandings which underpin the reporting of science and reasoned discourses about science and technology. Such literacy is required to engage with science-related issues as a reflective citizen (OECD, 2019).

Misunderstanding of science, health and medicine has been highlighted by reporting of the COVID-19 pandemic. An acute public appetite for information has resulted in circulation of misinformation, misconceptions and harmful claims (OFCOM, 2021). The World Health Organisation and OFCOM have warned of an 'infodemic' of misinformation posing a serious risk to public health (World Health Organisation, 2021).

A substantial proportion of the UK population feels that media reporting has made the situation worse. In many cases, rather than being completely fabricated, true information is spun, twisted, recontextualised and reworked into misinformation. Whilst some social media platforms say they take steps to remove false and potentially harmful posts, by their nature their fact-checking processes involve selection bias and cannot address every piece of misinformation (Brennen, et al., 2020).

An information deficit model has been cited as a cause of a lack of public response to the climate crisis, alongside apathy, ignorance and self-interest (Norgaard, 2011). Whilst it is acknowledged that increasing knowledge alone does not augment public trust in science, an understanding of climate science is arguably essential in underpinning informed public debate around the greatest modern-day challenge of our age.

Threshold concepts

Threshold concepts are transformative, troublesome, and difficult to grasp. Conceptual gateways or portals in disciplines, 'jewels in the curriculum' they can cause students to become anxious and stuck but once mastered they are unlikely to be forgotten. They can open conceptual spaces and transform identities and views of the world (Meyer & Land, 2005).

Land and Mayer suggested they have seven characteristics:

- transformative (involving a shift in learner's perception),
- troublesome (alien, counterintuitive and subversive),
- irreversible (unlikely to be forgotten),
- integrative (in terms of interrelatedness of concepts beliefs and theories),
- bounded (constrains the boundaries of the subject),
- reconstitutive (repositioning in relation to content)
- discursive (involves gaining new language related to the content).

For the journalism student or journalist getting to grips with reporting science, the concepts described in this paper share many of those characteristics. They are key to the journalist's understanding or misunderstanding of science (transformative and constitutive) often run counter to the traditional practices of journalism (troublesome but integrative) and become part of the language of critical discussion (discursive). They can be conceptually difficult, are potentially irreversible and bounded in terms of defining the science journalism curriculum.

Methodology

Action research and documentary analysis was conducted by observing student learning and the evolution of the curriculum during the teaching, design, and delivery of a 15-credit elective module to third year jour-

nalism undergraduates at two London universities between 2013 and 2018. Such research is characterised by Glynis Cousin as 'transactional curriculum design' in which dialogue between teachers, students and educationalists identifies threshold concepts within a subject area (Cousin, 2009).

The module was taught in groups of between 10 and 22 students. Conversations were facilitated between academics from scientific disciplines and students of journalism, many of whom had little or no scientific education, mathematical or statistical literacy.

In one session, undergraduate students were taken into a research lab to interview PhD students about their projects. In another, a professor of public health who had managed high levels of public anxiety about a cluster of childhood leukaemia cases led a classroom discussion about her investigation and the sensationalised news coverage it attracted.

After initial discussion about students' interests in and knowledge of science, health, medicine, technology and the environment, classes focussed on the relationship between science and society, the public's appetite for and understanding of science and the complexities of science journalism.

Students were required to critically reflect in an assessed essay discussing whether journalists were obliged to give the views of people with strong opinions equal prominence with those with compelling scientific evidence, with reference to a scientific controversy agreed with their tutor. Students were required to pitch and present their ideas and discuss with the class.

The second half of the module required students to produce an original piece of news, feature or multimedia journalism for a specific target audience including quotes from at least three original interviews. Again, students were required to pitch and present their ideas and discuss them with the class.

Topics proposed by students included the climate crisis, legalisation of recreational drugs, organic food, pesticides, gene editing, GM foods, fracking, animal testing, safety of video games, creationism, alternative medicine, artificial intelligence, microplastics, 5G communications, the safety of the HPV and MMR vaccines and therapeutic cloning.

Student feedback on the module was positive. Satisfaction with the module scored 4.3 out of 5. Responses to the question 'this lecturer is good at explaining things and has helped me understand the module' scored at 4.8 out of 5, and to the question 'this lecturer has made the module interesting' scored 4.6. Student comments included 'the lecturer encourages a lot of conversation between classmates which enhanced my learning and understanding' and 'we have been presented with many good resources and cases in order to further our understanding of the differences and similarities between general news journalism and science journalism'.

During repeated iterations of the course, it was found that discussion focussed and crystallised around key concepts which became transformative on student understanding. Particular attention is paid to concepts and ideas which could be considered counterintuitive to the traditional practices of journalism, connected to misreporting or misunderstanding of science or which became part of the language of discussion in the classroom.

In some cases, these became associated with 'stuckness' suggesting students might be caught in liminal spaces. These are proposed as threshold concepts involved in thinking like a science journalist rather than a news reporter and thus defining of the discipline of science journalism.

Understand the scientific method

Whilst the professions of science and journalism share significant characteristics (such as those of data collectors and a devotion to discovering the truth) their norms and practices of inquiry are fundamentally different (Schunemann, 2013).

In discussions about scientific experimentation it was found that many journalism students lacked appreciation and understanding of scientific methodologies and the language of reports. As a result, the purpose and meaning of scientific research was obscured.

It is acknowledged that the practices of the scientific community in constructing knowledge can be complex and influenced by societal and economic and philosophical considerations (Gregory & Miller, 2000). However, without basic knowledge and understanding of the practices of science it is impossible for the journalist to accurately depict the processes of science or critically interrogate scientific research.

The OECD suggests that scientific literacy involves not only content knowledge (the ability to recall and

use theories, explanatory ideas, information and facts) but procedural and epistemic knowledge of how scientific knowledge is established and an understanding of the common practices of scientific inquiry (OECD, 2019). Science journalists also need an appreciation of the limitations of processes of science and processes such as peer review (Blum, et al., 2006; Schunemann, 2013).

At its most basic, this involves an appreciation of how science collects and weighs evidence, makes declarations and predictions. Fundamental to much of that is an appreciation of the classic scientific method involving identifying a question and a hypothesis, setting up an experiment, analysing the resulting data and writing a report. Whilst on the surface this might appear similar to the practice of a news reporter, it is fundamentally different from the practices of journalistic inquiry.

In general, journalists use inductive reasoning, in which observations are questioned and hypothesised to reach a conclusion. Whilst scientists might use inductive reasoning to conceive a hypothesis or scientific experiment, the research itself involves deductive reasoning in which theories or hypotheses are tested to conclude whether they are true or false.

Deeper critical examination of scientific methodologies might identify issues involving sample sizes, control mechanisms, selective reporting of data, identification of research funded by industry or special interest groups or extrapolating results of tests on animals to humans. In medical and health reporting this might involve discussion about methodologies of clinical trials, randomisation, blinding or the placebo effect (European Communication on Research Awareness Needs, 2021).

Distinguish between the views of people with scientific evidence and those with strong opinions

Since debates over creationism and whether the earth was round or flat, views of scientists have been pitched against people who hold strong views which counter scientific consensus. Whilst few people would be inclined to say that the shape of the earth is still a matter of controversy, public disputes persist around science concerned with matters of belief or knowledge.

Such views may be influenced and informed by faith, personal beliefs, political or financial self-interest for example and may be justified and expressed in a number of ways. Statutory bodies such as legislatures, agencies and courts may be required to mediate between the views of establishment interests and challenge groups before making decisions. Objective scientific facts may influence their decision making but may not be the most important factor (Caplan & Engelhardt, 2003).

Increasingly scientific evidence is challenged using notions of ‘fake news’ and conspiracy theories. Such theories can often be driven by feelings of injustice, resentment or cynicism towards government experts and mainstream media and may proliferate on social media (Sense About Science, 2021).

Snow’s (1963) discourse about ‘confusion between the individual experience and the social experience, between the individual condition of man and his social condition’ is reflected in modern day narratives about the person who smoked all their life and lived into their nineties, the climate change denier during a spell of cold weather or the anti-vaccination campaigner discussing personal experiences around vaccination, for example.

In classroom discussion around reporting of the story involving the cluster of childhood leukaemia, stories involving unexplained cancer clusters or vaccination controversies, students often initially found it difficult to mediate between the evidence-based views of the scientific community and the strong views held by families of individuals who had been taken ill or died.

It is not suggested that such views should be dismissed or ignored in science journalism, particularly in ethical debates during which practices of science and technology are held to account in the public sphere. However, it is important that views and opinions and their motivations should be acknowledged and contextualised as such.

Beware the maverick and the miracle cure

The traditional practices of news journalism draw reporters to the unexpected, the unusual and the unlikely (McKane, 2014) yet in terms of critical reporting of science, such instincts can be unhelpful. As a result,

journalists who do not understand the nature of scientific discourse can pay undue attention to contrarian views because confrontation makes good copy. A fascination with unorthodox science can result in news media and social media offering a platform to amateur and unorthodox scientists and even conventional scientists who have been unsuccessful in publishing their work in peer-reviewed literature (Schunemann, 2013).

This can lead to misleading coverage of issues such as the climate crisis and vaccination, particularly in broadcast debates (Angler, 2017; Fox, et al., 2010; House of Lords Science and Technology Committee, 2000; Jones, 2011).

Whilst news journalists and social media audiences are naturally drawn to research producing unexpected or unlikely results, the scientific community is unlikely to draw conclusions from results of an individual study, particularly if they have not been confirmed in a replication study or elsewhere.

Journalistic use of the word "breakthrough" usually either overstates a finding or ignores the years of incremental successes preceding it. Stories of this nature might involve distortions, exaggerations, or changes of conclusions from research in press releases from universities (Goldacre, 2009; Sumner, et al., 2014) or as in the case of the MMR scare in 1998, giving prominence to the views of a rogue scientist.

Similarly, the 'lone genius' is a trope that gets aired routinely; 'the man in the shed inventing cold fusion'. In reality, science is almost always carried out in collaboration, frequently across different institutions (Gregory & Miller, 2000).

Practices of effective science journalism require the critical faculties to distinguish between serious scientific research and sensationalism and 'infotainment' of the type parodied by the US satirist John Oliver in his sketch about meaningless popular science coverage (Angler, 2017; Schunemann, 2013; Oliver, 2016).

Some of these stories might involve promotional activity from universities or commercial organisations; an academic posing as a human cyborg who has implanted a chip in his arm or another funded by an ice cream manufacturer to 'find a formula for the perfect way to eat ice cream' (Goldacre, 2009).

Similarly, Goldacre (2009) suggests that reporting of 'miracle cures' should be treated with scepticism. Whilst acknowledging a golden age of medicine between 1935 and 1970 involving new treatments such as kidney dialysis, CT scanners, heart surgery, and vaccines, Goldacre suggests that modern medicine does not generally move ahead by sudden epoch-making breakthroughs but rather through the gradual emergence of small incremental improvements in understanding (Goldacre, 2009).

Avoid false balance

Journalism students are taught that conflict is the main constituent of news stories, alongside celebrity, human interest, quirks and occasionally genuine science research and discovery (McKane, 2014). As a result, views of maverick scientists or people with strong opinions may be set against established scientific opinion with equal weight and equivalence.

In the context of the climate crisis, the satirist John Oliver makes the point in the sketch in which a debate between a scientist and a climate change sceptic is halted and reframed as a 'statistically representative climate change debate' in which the voices of a studio full of scientists drown out the sceptic (Oliver, 2014).

More recently, arguments about false balance resurfaced in the context of political debate about Brexit when the BBC's director of news suggested that an 'unthinking insistence on balance' between know-nothings and lightweights could have contributed to the problem of post-truth politics. Whilst acknowledging that it was not the BBC's job to preside over the democratic process it was acknowledged that in order to 'get beyond the noise to the news' resources needed to be put into data analysis and context (Harding, 2016).

Statistical literacy

Numbers saturate news headlines, politics and public life and underpin many areas of medical and scientific research. However, they are often misused and misinterpreted by the media and sometimes by scientists. Their use in news coverage can be vague, patchy and imprecise yet they are sometimes neither questioned nor interrogated by journalists (Cushion, et al., 2016).

The emergence of data journalism as a discipline has introduced instruction in the acquisition, cleaning,

analysis and presentation of data to the journalism curriculum. Less common is detailed instruction in statistical literacy, samples and populations or the critical thinking to detect biased or manipulated statistics and consideration of the ethical issues involved (Lewis, et al., 2020).

Whilst a science journalist might not require a degree in mathematics, they require basic numeric literacy, skills, knowledge and scepticism to critically interrogate discourses about statistics, risk and certainty (Blastland & Dilnot, 2008; Blum, et al., 2006). These might include mathematical skills such as distinguishing between percentages and percentage points, knowledge of concepts such as probability, absolute and relative risk, rates, and averages for example (Angler, 2017; Blastland & Dilnot, 2008) but also procedural, epistemic knowledge to analyse and interpret data and draw conclusions (OECD, 2019).

Within this epistemic knowledge, it is argued, lie more transformational, threshold concepts which run counter to the intuition of the news journalist. The concepts listed here emerged in an extension of the language of the science journalism classroom, suggested that they had the discursive quality required.

Correlation is not causation

Listening to loud music is correlated with acne, sleeping with one's shoes on is correlated with waking up with a headache, and ice cream sales with drowning, but in mistaking correlation for causation, journalists can flout one of the most elementary rules of statistics (Angler, 2017; Blastland & Dilnot, 2008). In the cases described above, establishment of causation would involve identification of a mechanism linking two variables where there is none.

Science journalists need to have an appreciation of the impact of confounding factors such as age, consumption of alcohol or hot sunny weather which can erroneously suggest a cause-and-effect relationship. Such an attitude might run counter to the instincts of a news journalist who might be fooled into thinking that 'there is no smoke without fire'.

Confusion between correlation and causation may occur inadvertently in a badly-written headline or social media post but it might also result from more deliberate manipulation of statistics by reporters or researchers through practices such as data dredging, selective interference or 'p-hacking' in which data is selectively presented by scientists under pressure to publish or secure funding for research (Angler, 2017).

Blastland and Dilnot (2008, p.205) suggest that the ability to spot errors involving spurious correlation errors depends on how fast a better explanation comes to mind. They suggest the use of prompts to the imagination such as 'what else could be true of the group, the place, the numbers we are interested in? What other facets do they share, what else do we know that might help to explain the patterns we see?'.

Chance event clusters

In health reporting, clusters of diseases in spaces around mobile phone masts, or in time around vaccination events, for example, may be explained as chance event clusters, patterns which appear in random distributions.

The practices of news journalism might encourage the identification of chance event clusters through the Texas Sharpshooter Fallacy, in which differences in data are ignored and similarities are overemphasised. The reference to the sharpshooter involves an unskilled gunman who shoots randomly at a barn and draws a target afterwards around the tightest clusters of holes (Blastland & Dilnot, 2008).

The news journalist trained to seek out the unusual might give undue prominence to such events in time or in geography. They may not appreciate that such patterns appear naturally, when rice is thrown on to a floor, for example, or outbreaks of disease are plotted on a map.

To illustrate the phenomenon. science journalism students were provided with an Excel spreadsheet which when refreshed produced a random distribution of cells all of which contained clusters of events.

Regression to the mean

Minor illnesses usually get better without treatment, football clubs at the top of the table rarely maintain their success and statistical variables with normal distribution which are extreme on first measurement tend to be closer to average on a second measurement. The phenomenon whereby things at extremes are likely

to settle back down to the middle is called ‘regression to the mean’.

Critics of homeopathy maintain this explains its apparent success in treating back pain, and other episodic diseases (Goldacre, 2009).

Again, the inductive reasoning practices of news journalism would intuitively seek a cause for a statistical peak or decline. Whilst not all such peaks will regress, the science journalist should have the skills and awareness to recognise these patterns as such and consider them as part of their critical reporting skills.

Conclusion

Whilst science journalism might traditionally be considered a niche specialism, the emergence of issues such as vaccine hesitancy and climate change denial has highlighted the societal importance of accurate and informed reporting on the processes of science, technology, health and the environment.

Despite the emergence of data skills as part of the core journalism curriculum, journalism academics continue to broadly reflect the profile of the profession of journalism in which the majority tend to identify as literary intellectuals rather than scientists or statisticians.

Whilst concepts outlined above were identified during specialised training for science journalists, they are proposed for inclusion in the general journalism curriculum, either as part of a dedicated session on reporting science, health, technology and the environment or through more general discussion about news and current affairs.

Discussion of responsible reporting of the climate crisis might provide an opportunity to discuss false balance, correlation and causation and distinguishing between the views of people with strong opinions and those with scientific evidence for example.

Discussion around the reporting of COVID-19 vaccine hesitancy might involve discussion of maverick scientists. Chance event clusters can explain incidences involving vaccine side effects whilst regression to the mean remains a helpful concept in critical reporting on alternative medicine.

It is hoped that the by getting to grips with some of threshold concepts above, journalism educators could develop their own critical skills and those required of journalism students to report on science, technology and statistics.

Bibliography

Angler, Martin (2017) Science Journalism: An Introduction. Oxford: Routledge.

Blastland, Michael and Dilnot, Andrew (2008) The Tiger That Isn’t: Seeing Through a World of Numbers. London: Profile.

Blum, Deborah; Knudson, Mary and Marantz Henig, Robin (2006) A Field Guide for Science Writers. 2nd ed. Oxford: Oxford University Press.

Brennen, J. Scott; Simon, Felix M.; Howard, Philip N. and Nielsen, Rasmus K. (2020) Types, Sources, and Claims of COVID-19 Misinformation. [Online]
Available at: https://reutersinstitute.politics.ox.ac.uk/types-sources-and-claims-covid-19-misinformation [Accessed 3 September 2021].

Caplan, Arthur and Engelhardt, H. Tristram (2003) Scientific Controversies: Case Studies in the Resolution and Closure of Disputes in Science and Technology. Cambridge: Cambridge University Press.

Castell, Sarah; Charlton, Anne; Clemence, Michael; Pettigrew, Nick; Pope, Sarah; Shah Jayesh Navin and Silman, Tim (2014) Public Attitudes to Science , London: Ipsos MORI.

Cousin, Glynis, 2009. Researching Learning in Higher Education, an Introduction to Contemporary Methods and Approaches. Abingdon: Routledge

Cushion, Stephen; Lewis, Justin and Callaghan, Robert (2016) Data Journalism, Impartiality And Statistical Claims. Journalism Practice, 11(10), pp. 1198-1215.

Department for Business, Energy and Industrial Strategy (2020) Public Attitudes to Science 2019. [Online]

Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/905466/public-attitudes-to-science-2019.pdf
[Accessed 17 September 2021].

European Communication on Research Awareness Needs (2021) ECRAN. [Online]
Available at: http://www.ecranproject.eu/
[Accessed 7 September 2021].

Fox, Fiona; Saxon, Alex; Ward, Bob; Beckett, Charlie; Blakemore, Colin; Glover, David; Levy, David and Unsworth, Fran (2010) Science and the Media: Securing the Future. [Online]
Available at: https://webarchive.nationalarchives.gov.uk/ukgwa/20120708131732/http://interactive.bis.gov.uk/scienceandsociety/site/media/2010/01/21/comment-on-the-final-report/
[Accessed 7 September 2021].

Goldacre, Ben (2009) Bad Science, London: Fourth Estate.

Gregory, Jane and Miller, Steven (2000) Science In Public: Communication, Culture, And Credibility. New York: Basic Books.

Harding, James (2016) A Truly Balanced View from the BBC: Don't Blame us for Brexit. [Online]
Available at: https://www.theguardian.com/commentisfree/2016/sep/24/dont-blame-bbc-for-brexit-false-balance
[Accessed 13 September 2021].

Hartz, Jim and Chappell, Rick (1997) Worlds Apart: How the Distance Between Science and Journalism Threatens America's Future, Nashville: First Amendment Center.

House of Lords Science and Technology Committee (2000) Science and Technology - Third Report. [Online]
Available at: https://publications.parliament.uk/pa/ld199900/ldselect/ldsctech/38/3801.htm
[Accessed 1 September 2021].

Jones, Steve (2011) BBC Trust Review of Impartiality and Accuracy of the BBC's Coverage of Science. [Online]
Available at: https://downloads.bbc.co.uk/bbctrust/assets/files/pdf/our_work/science_impartiality/science_impartiality.pdf
[Accessed 1 September 2021].

Lewis, Norman P.; McAdams, Mindy and Stalph, Florian (2020) Data Journalism. Journalism and Mass Communication Educator, 75(1), pp. 16-21.

McKane, Anna (2014) News Writing. 2nd ed. London: Sage.

Meyer, Jan H. & Land, Ray (2005) Threshold Concepts and Troublesome Knowledge (2): Epistemological Considerations and a Conceptual Framework for Teaching and Learning. Higher Education , Volume 49, pp. 373-388.

Nelkin, Dorothy (1987) Selling Science, How the Press Covers Science and Technology. New York: Freeman.

Norgaard, Kari Marie (2011) Living in Denial: Climate Change, Emotions, and Everyday Life. Cambridge Massachusetts: The MIT Press.

OECD (2019) PISA 2018 Science Assessment and Analytical Framework. [Online]
Available at: https://www.oecd-ilibrary.org/sites/f30da688-en/index.html?itemId=/content/component/f30da688-en
[Accessed 7 September 2021].

OFCOM (2021) Combatting Covid-19 Misinformation. [Online]
Available at: https://www.ofcom.org.uk/research-and-data/media-literacy-research/coronavirus-resources
[Accessed 17 September 2021].

Oliver, John (2014) Climate Change Debate: Last Week Tonight [Online]
Available at: https://www.youtube.com/watch?v=cjuGCJJUGsg
[Accessed 8 September 2021].

Oliver, John (2016) Scientific Studies: Last Week Tonight. [Online]
Available at: https://www.youtube.com/watch?v=0Rnq1NpHdmw
[Accessed 17 September 2021].

Schofield, Barbara and Franks, Suzanne (2020) QUEST – Curriculum on Science Journalism. [Online]
Available at: https://questproject.eu/download/quest-curriculum-on-science-journalism/

[Accessed 6 September 2021].

Schunemann, Sophie (2013) Science Journalism in Wheeler, Sharon; Turner, Barry and Orange, Richard eds. Specialist Journalism. Abingdon: Routledge, pp. 134-146.

Science Media Centre (2021) Science Media Centre. [Online]
Available at: https://www.sciencemediacentre.org/
[Accessed 11 August 2021].

Sense About Science (2021) Sense about Science. [Online]
Available at: https://senseaboutscience.org/
[Accessed 6 September 2021].

Sense About Science (2021) Talking about COVID Conspiracy. [Online]
Available at: https://senseaboutscience.org/activities/talking-about-conspiracies/
[Accessed 15 September 2021].

Snow, Charles Percy (1963) The Two Cultures: And a Second Look: An Expanded Version of The Two Cultures and the Scientific Revolution. Cambridge: Cambridge University Press.

Sumner, Petroc; Vivian-Griffiths, Solveiga; Bolvin, Jacky & Williams, Andy (2014) The Association between Exaggeration in Health Related Science News and Academic Press Releases. British Medical Journal, 349(7987).

World Health Organisation (2021) Infodemic Management. [Online]
Available at: https://www.who.int/teams/risk-communication/infodemic-management
[Accessed 3 Setptember 2021].