V-KEMS Study Group Report

The Public Perception of Science

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WARNING: this report contains preliminary findings that have not been peer reviewed. The findings are intended to provoke further study and policy discussion and should not be treated as definitive scientific advice in response to the COVID-19 pandemic.

Whilst we expect these principles to help others formulate coherent and consistent guidelines, time has prevented any quantitative study of their effectiveness. This could be undertaken, but would require real data and time to build more detailed simulation tools. Thus, we are not able to make specific recommendations from the principles, e.g. we cannot infer that it is safe to do X if you follow principle Y.

Additionally, this report has been assembled in a short time frame, we have made every effort to ensure references and links are present. Where this is not the case, we apologise for the unintentional oversight.

Contents

1 Executive Summary

This three-day virtual study group explored the challenges related to scientific misinformation/miscommunication in the media and the impact of the COVID-19 pandemic on scientists. It aimed to bring mathematical scientists and other disciplines together to solve end user defined challenges with the aim of addressing the issues associated with the public perception of science. It featured talks and insights from Dr Kit Yates *(University of Bath)*, Professor An Nguyen *(Bournemouth University)*, Rachel Thomas *(Plus Magazine)* and Dr Fiona Lethbridge *(Science Media Centre)*. In addition, the following challenges were presented to the study group:

- **Challenge 1 – Trustworthy Communication – Winton Centre**

  This challenge asked "How trustworthy was the communication of evidence during the pandemic? Did trustworthiness have any impact?" and will was facilitated by researchers from the Winton Centre Sarah Dryhurst, John Kerr, and Claudia Schneider across the three days.

- **Challenge 2 – Communicating Mathematics – The Times**

  This challenge asked "How can we train mathematicians to communicate & how can we work with journalists and policy makers effectively?"

- **Challenge 3 – Misinformation – Office for Statistics Regulation**

  This challenge asked "How can we distinguish between misleading uses of statistics, data and evidence, and legitimate alternative interpretations of the same underlying evidence?" and featured insights from Kirsty Garratt, Suzanne Halls, Ed Humpherson and Helen Miller-Bakewell from OSR.

Over the course of the study group, potential solutions were developed and these were presented on the final day. Those stakeholders who presented their challenge were provided with a short tailored report after the event.

2 Background

This three-day virtual study group explored the challenges related to scientific misinformation/miscommunication in the media and the impact of the COVID-19 pandemic on scientists.

The COVID-19 Pandemic has impacted many lives of people across the world. This has meant that the public was more than ever keen to (and had a need to) know the latest and most accurate science. In addition, scientists were under immense pressure to not only produce quality research under tight timescales, in order to help the UK government form policies and make decisions, but also to communicate their findings to audiences from both scientific and non-scientific backgrounds, both on television, radio and on social media platforms.

The influence of news outlets and social media on society has implications on the public perception of science. As discussed in the Royal Society's report on 'The online information environment', the algorithms used on social media platforms mean that people see more of what they like, and this may help form a particular way of thinking. The negative effects of this influence are exacerbated when misinformation is spread, causing confusion and misunderstandings. Furthermore, scientists are faced with directly dealing with praise and scrutiny of their research through their social media platforms.

2.1 Aims & Objectives

This event aimed to bring mathematical scientists and other disciplines together to solve end user defined challenges with the aim of addressing the issues associated with the public perception of science. The challenge areas were:

Challenge 1 – Trustworthy Communication – Winton Centre

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The study group also featured talks from:

Dr Kit Yates *(University of Bath)* – Kit covered challenges of communicating maths specifically, as well as general science communication and his experiences as part of Independent SAGE and in different media outlets.

Professor An Nguyen *(Bournemouth University)* - regarding building a working relationship between statisticians and journalists

Rachel Thomas *(Plus Magazine)* - regarding their experience as science communicators within JUNIPER and beyond.

Dr Fiona Lethbridge *(Science Media Centre)*

3 Challenge 1 : Trustworthy Communication

3.1 Research Questions

- How can we define trustworthy communication? Qualitative, quantitative?
- Can we score communications for their match to the rules/markers of good evidence communication?
- How can we measure the impact of trustworthy communication?
- Can we understand from comments and links on posts etc whether information about the pandemic was perceived as trustworthy?

3.2 Aims

- Definitions of trustworthiness
- Scoring the trustworthiness of visualisations
- Measuring the impact of verbal posts or visualisations (e.g. on Twitter) in terms of likes, shares etc

Using these definitions/frameworks of trustworthiness, can we score posts and visualisations, and link this to their impact?

3.3 Definitions of trustworthiness

3.3.1 Discussion Notes

Trustworthiness is the social concept, generally meaning something that can be trusted or relied upon. As any social concept, the notion will depend on the society in question, on the topic and will evolve with time.

Trust in itself is a social belief in the:

- reliability (stability under changes),
- truth (testable data),

- ability (subjective evaluation of potential).

In relation to science communication trustworthiness will be determined by three main factors: the producer, the receiver, and the content.

- The producer: what is their intent, what are their sources of information, do they have individual agendas and will there be a pre-existing bias/unconscious bias.
- The receiver: what is their baseline/depth of understanding of the area, pre-existing bias/unconscious bias.
- The content: is the balance of evidence presented where appropriate or an acknowledgement of a consensus given, the sources of information, is appropriate language used, and, are statistics relative and representative.

An awareness that trustworthy communication will be designed and evaluated on a 'best-practice' level and it is impossible to pre-empt how individuals within a population group will react to and understand communication. Therefore it is essential to evaluate the impacts of communication and ensure that negative impacts are minimised.

Additionally the smaller the population group the more achievable targeted communication is. Additionally these factors in a Western country will vary greatly when looked at on a global level.

Discussing the idea of trust vs trustworthiness. Extended discussion of the time-scale and scope of the work.

"Trust is valuable when placed in trustworthy agents and activities, but damaging or costly when (mis)placed in untrustworthy agents and activities." Onora O'Neill (2018)

It is not possible with the time and resources given to effectively analyse the producer, the receiver and the content. Additionally, the producer and receiver will be influnced by a number of sociological factors. Therefore herein we are focusing on the **trustworthiness of content** rather than the generation of trust.

A bird's eye view on what factors could be used to generate or evaluate trustworthiness. This does not consider the agenda/intent of the producer, nor does it consider if the trustworthy communication will generate trust in the receiver.

3.3.2 Workplan

- Introduction - setting the scene as to the scope of the work. Discussion of trust/trustworthiness and differences/overlap. Working definition of trustworthiness in relation to science communication.
- Setting the scene -Discussion of the focus of the work. Why we have chosen to focus on the trustworthiness of content. What we are not considering but do acknowledge
- Table - a table that could be used as an assessment tool to generate/evaluate trustworthy communication.
- Limitations of the table - future work could assess the evaluation criteria in real settings and work towards developing a points based scoring system for the number of criteria met. The table won't consider all factors relating to all types of communication e.g. verbal/visual/written.
- Discussion - how trustworthy communication can be used by producers for ethical/unethical reasons e.g. trust vs misplaced trust. Regardless of intent and 'best-practice' content and acknowledgement of the number of human and sociological factors that will affect the relationship between trustworthy communication and the generation of trust.

3.3.3 Background

Trustworthiness is the social concept, generally meaning something that can be trusted or relied upon. As any social concept, the notion will depend on the society in question, the topic, and will evolve with time. Trust is a complex and multifaceted concept and is described as "essential for the existence of social capital" (Coleman, 1990). Whilst there is no one definition of trust, it can be described as the social belief in the reliability (stability under changes), truth (testable data), and ability (subjective evaluation of potential). However, it is important to recognise that trustworthy communication will not necessarily ingender trust. Claridge *et al* (2020) describe that trust is "a calculation and predisposition that is socially and culturally situated, so has an element of intersubjectivity, and is grounded in subjective experience", this in-part explains why something that can be described as trustworthy will not always ingender trust.

Trust and trustworthiness are concepts that will be ingrained in all human interactions, therefore this work focuses on trustworthiness in relation to science communication only. We theorise that the trustworthiness of science communication is determined by three main factors: the producer, the receiver, and the content.

- The producer: what is their intent, what are their sources of information, do they have individual agendas and will there be a pre-existing bias/unconscious bias.
- The receiver: what is their baseline/depth of understanding of the area, pre-existing bias/unconscious bias, socio-demographic factors and subjective experiences.
- The content: is the balance of evidence presented where appropriate or acknowledgement of a consensus is given, is appropriate language used, and are the data/statistics relative and representative.

3.3.4 Approach

Given the time and resource availability of this project it is not possible to effectively analyse the producer, the receiver and the content. Additionally, the producer and receiver will be influenced by a number of sociological factors. Therefore, our aim is to take a "bird's eye view" on what factors could be used to generate or evaluate the **trustworthiness of science communication content**. This does not consider the agenda/intent of the producer, nor does it consider if the trustworthy communication will generate trust in the receiver.

To generate and evaluate the trustworthiness of science communication content we have designed an assessment tool. The tool, presented in the table below, aims to theoretically evaluate or generate trustworthy communication. The table was built using a series of factors found within scientific communication and evaluation criteria generated as a series of reflective questions to prompt further reflection of science communication content and its trustworthiness.

3.3.5 Limitations

The tool is not without limitations as the tool has not yet been tested for use in real world settings. Firstly, the tool groups scientific communication as a whole and does not take into account the unique nuances to the type of communication being assessed, namely visual, verbal and written. Furthermore, the tool is reflective and does not feature a scoring system, therefore a binary measure of trustworthiness cannot be obtained, making it more difficult to compare multiple sources of communication. The reflective nature of the tool also prevents it from taking into account the first impressions of trustworthiness held by the receiver – they may carefully reflect on communications when using the tool, however in their day-to-day life may not read the information as carefully. Finally, as the tool is focused on the content of informa-

Factor	Description	Evaluation criteria
Source of information	Are the source(s) of information stated?	Are the sources reputable? Are the sources referenced? Are the sources accessible? Are the sources open access? Is the original source given? (e.g. not a screen shot)
Language	Does the language meet the needs of the receiver/purpose?	Is the language used appropriate for the target audience? Is terminology explained? Are abbreviations explained? Is lay language used (where appropriate)? Are 'emoji's' used appropriately? (where relevant)
Statistics/ quantitative data	Does the communication use quantitative data and/or statistics?	Are they understandable? Are they reproducible? Are they verifiable? Are uncertainties (e.g. confidence intervals) given? If yes, is their context explained? Are visualisations used? (Where appropriate)
Qualitative data	Does the communication use qualitative data?	Are they understandable? Are they representative? Are they generalisable? Are the methods of analysis disclosed? Are the limitations/caveats acknowledged?

Table 1: Prototype assessment tool for trustworthy science communication.

Factor	Description	Evaluation criteria
Balance of evidence	Does the information presented represent all aspects of the topic equally?	Are multiple arguments considered? Are the arguments balanced appropriately? Is the balance reflective of the literature?
Consensus/ conclusion	Is there a consensus or conclusion given?	Does this line up with the balance of evidence? Are the assumptions of the conclusion given? Is the conclusion objective?
References	Have references been used adequately?	Are there in-text citations? Are the references available? Are the references accessible to the audience?
Platform	Where is the content available?	Is it available on multiple platforms? Are the platforms accessible to all? Is it communicated away from the original source? If yes, is the source available? Are the platforms appropriate for the content?
Continuity	If this is part of a series of work, is it cohesive with previous versions?	Does a new method/visualisation change? If yes, is this well explained? Are previous editions/versions still available and accessible? Are changes communicated and explained to the receiver?

Table 2: Prototype assessment tool for trustworthy science communication - continued.

tion, it does not take into account both the producer or receiver and as such cannot ascertain both the intentions behind the production of the information, or the establishment of trust.

3.3.6 Discussion

Whilst the tool aims to assist in the generation of trustworthy content it does not consider the intent of the producer. Therefore, trustworthy communication may be developed for unethical reasons and generate mistrust misinterpreted as trust. This could be used negatively to aid the spread of conspiracy theories and disinformation. Onora O'Neill (2018) said *"Trust is valuable when placed in trustworthy agents and activities, but damaging or costly when (mis)placed in untrustworthy agents and activities."*, this mirrors our consideration and poses the necessity to ensure that the tool is actively developed to prevent its mis-use. This mis-use may be intentional or unintentional and therefore it is important that the tool is effectively explained, including its limitations, so that users can make informed decisions of its practicality for their work.

The receiver of any given information will always vary as different people will have differing interpretations of the information i.e. what is deemed trustworthy to person A, may instead be deemed untrustworthy by person B. Verma et al (2018) outline some of the key demographic characteristics that can impact the perception of trust, such as gender, age, political beliefs, education level and frequency of social media use. It is this variation in the identity of the receiver that can prevent content that was designed to be trustworthy from establishing trust.

There are numerous other factors and assumptions that have affected the design of this assessment tool and would affect its implementation in real-world settings. The work produced takes a birds eye view on a subsection of a broad and complex topic.

3.3.7 Conclusion

To conclude, the prototype assessment tool described provides a structured and reflective process that aims to improve the trustworthiness of science communication. Future work should aim to assess the usability and reliability of the tool and furthermore consider the influences that producers and receivers will have upon its efficacy.

3.4 Scoring the trustworthiness of visualisations

Creating a framework for scoring the trustworthiness of visualisations

3.4.1 Visual trustworthiness

We suggest considering how well a visualization supports the viewer's ability to accurately perceive and interpret information as the visualization designer intended it to be conveyed. This form of trustworthiness essentially relates to how much a viewer can trust their visual perception of a data visualization and therefore does not necessarily relate in any way to the trustworthiness of the visualization designer or the data source.

We feel it is worth considering this separately because it is possible to design a visualization which is entirely correct and truthful, yet still contains features that may mislead the viewer.

For situations where visualizations are being widely shared, particularly for communication to the general public, the designer cannot be assured that it will be viewed in exactly the conditions they would prefer. For instance, they cannot know:

- How much time the viewer spends looking at the visualization
- How focused their attention will be
- Whether the viewer will carefully read the title, axis labels, legend, captions etc.
- How the visualization is shared (e.g. a screenshot which removes a caption)

We propose that a visualization is more visually trustworthy when it is less likely to be misinterpreted by or to deceive even an inattentive viewer.

This form of trustworthiness will not apply to all situations where data visualizations are used, for instance it may not be relevant for expert users, or in cases where the designer expects the user to spend more time exploring a visualization, for instance, [Hullman et al., 2011] describes how increasing visual difficulty can lead to improved understanding.

Assessing the trustworthiness of a visual representation

Features that could increase the likelihood of misinterpretation:

- Inverted axes: this can lead to a viewer reversing the message [Pandey et al. 2015] and is also harder to interpret [Woodin, 2022]

- Truncated axes: can distort and exaggerate difference [Pandey et al. 2015]

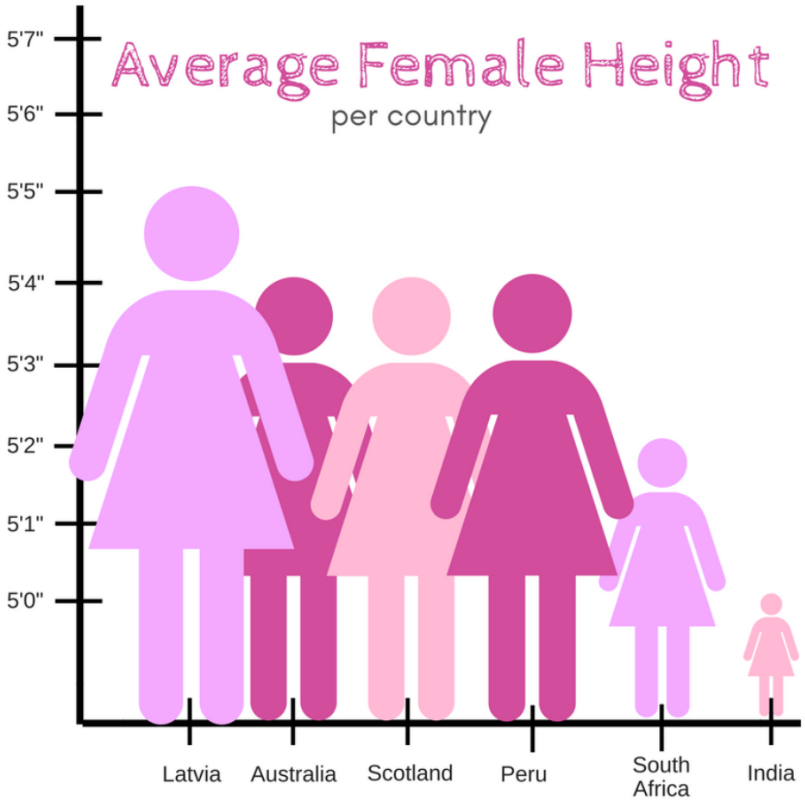


Figure 1

- Non-linear scaling (such as using size to represent values, but mapping the value to radius rather than area): distorts and exaggerates difference [Pandey et al. 2015]
- Distorting aspect ratio: distorts and exaggerated or understatement of difference [Pandey et al. 2015]
- Using colour in ways that go against existing biases (e.g. dark-is-more [Schiewe, 2019] and opaque-is-more [Schloss et al., 2019])
- Using poorly designed colour maps (e.g. where perceptual difference does not mirror value difference [Szafir & Gleicher, 2016], or where colour difference is not sufficient for the type of mark used [Szafir, 2018] or rainbow colour map: introduces artifacts [Borland & Taylor Ii, 2007])
- '3D' charts in 2D media: can occlude and distort values [Szafir, 2018]
- Dual axes: could lead viewers to infer false correlations

- Uneven binning of categorical colour maps
- Inappropriate use of diverging colour maps (e.g. where the data has no meaningful divergence, or where the 'zero point' is inappropriately placed – this needn't be zero, but it must be meaningful)
- Not matching scales for plots displayed side-by-side
- Inappropriate use of colours which convey a meaning (e.g. red, amber and green)
- Non-linear axes (e.g. log-scale): for the general public, this could potentially be misunderstood

This is not to imply that none of these features should ever be used. There are many situations where they may be appropriate, but it may be important to draw extra attention to these features in communications intended for the general public.

Anshul Vikram Pandey, Katharina Rall, Margaret L. Satterthwaite, Oded Nov, and Enrico Bertini. 2015. How Deceptive are Deceptive Visualizations? An Empirical Analysis of Common Distortion Techniques. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). Association for Computing Machinery, New York, NY, USA, 1469–1478.

Woodin, Greg et al. "Conceptual Metaphor and Graphical Convention Influence the Interpretation of Line Graphs." IEEE transactions on visualization and computer graphics vol. 28,2 (2022): 1209-1221.

Schiewe, J. Empirical Studies on the Visual Perception of Spatial Patterns in Choropleth Maps. KN J. Cartogr. Geogr. Inf. 69, 217–228 (2019).

Schloss, K. B., Gramazio, C. C., Silverman, A. T., Parker, M. L., & Wang, A. S. (2019). Mapping Color to Meaning in Colormap Data Visualizations. IEEE Transactions on Visualization and Computer Graphics, 25(1), 810–819.

D. Borland and R. M. Taylor Ii, "Rainbow Color Map (Still) Considered Harmful," in IEEE Computer Graphics and Applications, vol. 27, no. 2, pp. 14-17, March-April 2007

Authors interpretation of data

- Source cited and linked
- Axes labels consistent

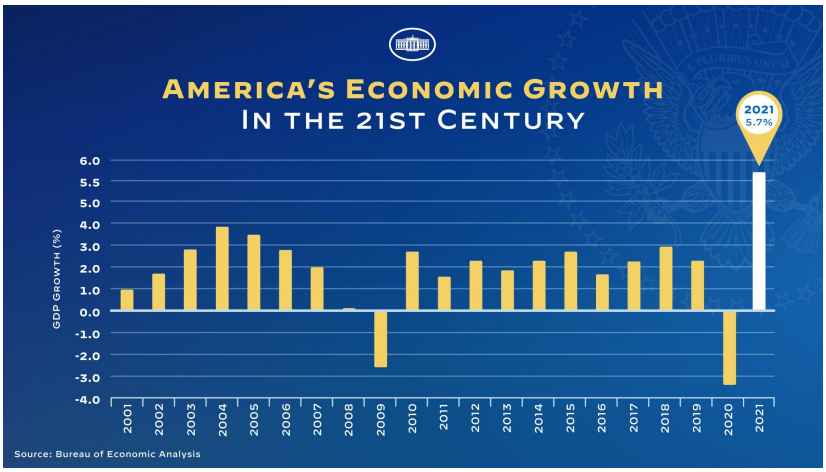


Figure 2

- Made clear reasons for deviation from 'normal' plot
- If intention is that no conclusion can be drawn: be open about that
- Is argument that they are making rational? Emotional? Argumentative? Mocking?

Rate 0-4 for each critereon

3.4.2 Rating framework

Shown in Tables 3 and 4.

3.4.3 Scoring

Visual trustworthiness: sum of 3 sections.

Author trustworthiness: sum of 3 sections.

Green (shows signs of trustworthiness): 2 or 3

Amber (mixed or neutral trustworthiness): -1, 0, 1

Red (shows signs of untrustworthiness): -2 or -3

Final score is lower of the two.

Factor	**Subfactors**	**Criteria/Guidelines**	**Scoring Agree: +1 Neither: 0 Disagree: -1**
Visual Trustwor-thiness	Axes	Features that may lead to mis-interpretation: - Inverted axes - Truncated axes - Dual axes - Non-matching scales for side-by-side plots - Non linear axes	Axes are not used in ways likely to lead to misinterpre-tation
	Colour	Features that may lead to mis-interpretation: - Goes against existing biases or expecta-tions (e.g. dark-is-more bias) - Poorly designed colour maps - Uneven or inappropriate bin-ning of categorical colour maps - Inappropriate use of diverging colour maps - In-appropriate or leading use of colour which convey meaning (e.g. green = good/safe)	Colours are not used in ways likely to lead to misinterpreta-tion
	Scaling	Features that may lead to mis-interpretation: - Distortion of aspect ratio - 3D charts in 2D media - Non-linear scaling of visual elements for linear in-crease in value	Scaling is not used in ways likely to lead to misinterpreta-tion

Table 3: Prototype assessment tool for trustworthy science communication.

Factor	**Subfactors**	**Criteria/Guidelines**	**Scoring Agree: +1 Neither: 0 Disagree: -1**
Author Trustworthiness	Plot elements	- Where applicable, reasons for deviation from conventions are made clear - Axis labels are clear and scales have not been manipulated - Consistency of design over series of plots concerning same issue - Ownership of plot made clear (e.g. logo of organisation) - Titles and subtitles relevant to plot (no contradictory/vague language)	The visualization design exhibits honesty, clarity and transparency
	Communication about the visualization	- If intention is that no conclusion can be drawn: be open about that - Is argument that they are making rational? Emotional? Argumentative? Mocking? - Has any highlighting of data been explained (e.g. why a certain bar has been coloured red)	Communication around visualisation is clear, honest, unbiased and transparent
	Data	- Source is cited and linked - Viewer can find and access the specific data used - Open about uncertainty of data (e.g. margin of error) - Open about how data has been processed	Author is transparent about the data used

Table 4: Prototype assessment tool for trustworthy science communication.

3.4.4 Examples

1. Assessment of Figure 3.

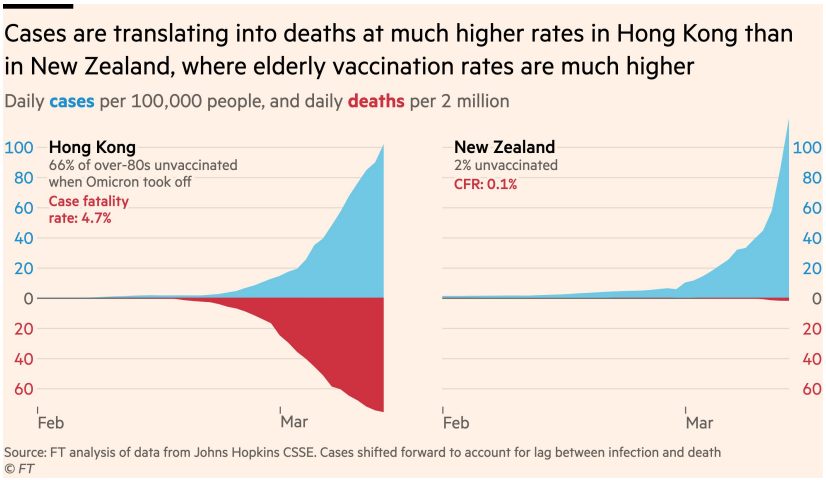


Figure 3

Visual trustworthiness:

Axes: Possible issues - inverted axis for deaths (although this facilitates comparison), cases and deaths axes are scaled differently. -1

Colour: No issues - colour matches with conventions +1

Scaling: No issues +1

Author trustworthiness:

Plot elements: Good - clear labelling, ownership, consistency between plots +1

Communication: No issues +1

Data: Good - source is given and author is transparent about processing +1

Visual score: +1

Author score: +3

Final score: Amber - mixed trustworthiness

In this case there are some reasons why initial perception may give an incorrect impression, however the author shows signs of trustworthiness.

2. Assessment of Figure 4.

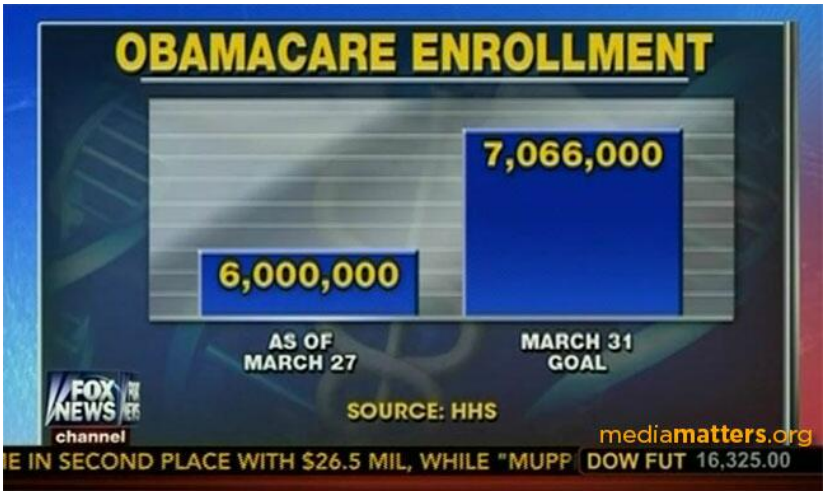


Figure 4

Visual score: +1 - amber **Author score:** -2 - red

Final score: red - shows signs of untrustworthiness

There are some visual aspects that could lead to misinterpretation and the author has shows signs of untrustworthiness.

3.4.5 Limitations and future work

Scoring system may need adjustment

May need to provide a different weighting when one element is particularly untrustworthy

Ideally empirical evaluation of how misleading each element is in practice

These factors will not apply in all cases (e.g. for expert viewers or specialist visualization types) but we feel they can provide support for assessing common visualization types meant for communicating information to the general public

3.5 Measuring the impact of verbal posts or visualisations

3.5.1 Introduction

Two potentially useful markers of trustworthy communications include being upfront about uncertainty in the numbers and facts being communicated (Blastland et al. 2020), and avoiding the use of overly emotive (positive or negative) language (Roozenbeek & van der Linden, 2019).

Looking at tweets from a selection of news outlets over a set period of time, we hope to measure the amount of uncertainty communicated by these outlets, and the extent to which they use emotive language. Such information can then be related to metrics such as the attention posts from these news outlets get over this same time period (e.g. likes, shares, comments), allowing us to infer whether those outlets that are more or less "trustworthy" according to our markers are receiving more or less attention.

We also plan to look at the amound of emotive and uncertainty content within comments on these posts, to see the type of engagement the tweet is receiving, and whether this information can yield further insights into the trutworthiness of the original communications and news outlet, based on our metrics.

Our chosen twitter news outlets include:

- @BBCNews (13.9M followers)
- @MailOnline (2.7M followers)

We will look at all tweets from each of these outlets across the 60 hours from 22:00h 17th May - 10:00h 20th May 2022.

3.5.2 Methodology

Aims

- Calculate the amount of uncertainty expressed across all tweets from 22:00h 17th May - 10:00h 20th May 2022, for each news outlet in turn
- Calculate the amount of positive/negative language used across all tweets from 22:00h 17th May - 10:00h 20th May 2022, for each outlet in turn

- Measure the amount of engagement these outlets get over the same time window (number of comments, likes, retweets).
- Measure the amount of uncertainty/amount of emotive language in comments on the scraped tweets, for each news source
- Plot how audience engagement varies with time
- Measure the relationship between amount of uncertainty/emotive language used by each news outlet and the level of engagement with its tweets

Research Questions

- Does the amount of uncertainty/emotive language used in tweets vary between news outlets?
- Does the amount of uncertainty/emotive included in tweets affect the amount of attention/engagement those tweets get?
- Are there common patterns in how level of attention to news outlets and individual tweets change over time?

Analysing tweets

In this part of the report, we have listed the instruction to access to Twitter API and listed the brief work flow done during the Study Group and potential future work could be extended to provide full analysis of the questions proposed during the event.

Work flow:

- targeted a few individual tweets and comments following those tweets.
- sentiment analysis of those tweets and comments.
- sentiment metric (average sentiment score) of tweets are calculated based on the sentiment analysis
- Time series constructed based on the metric of studied tweets.
- News tweets have been extracted

Figure 5: https://twitter.com/premnsikka/status/1526842330980188162

Figure 6: https://twitter.com/SkyNews/status/1526805109551861760

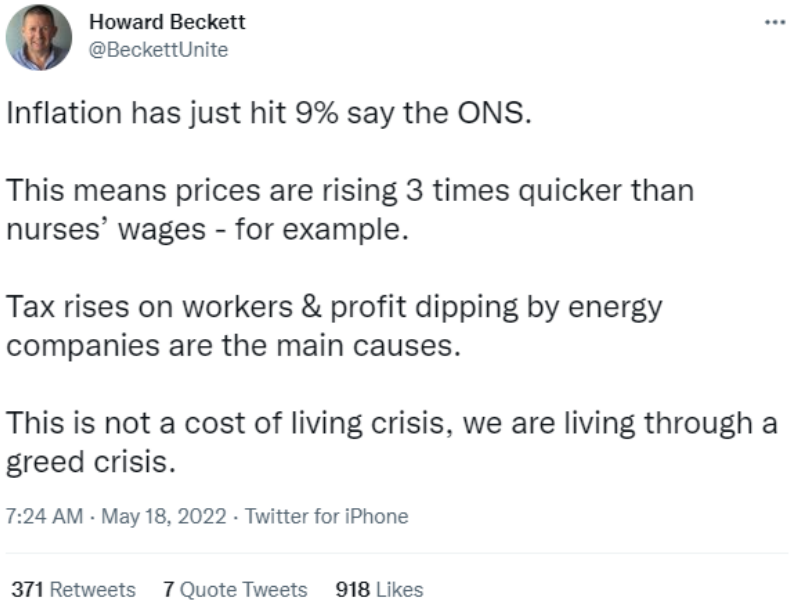


Figure 7: https://twitter.com/BeckettUnite/status/1526811064029020162

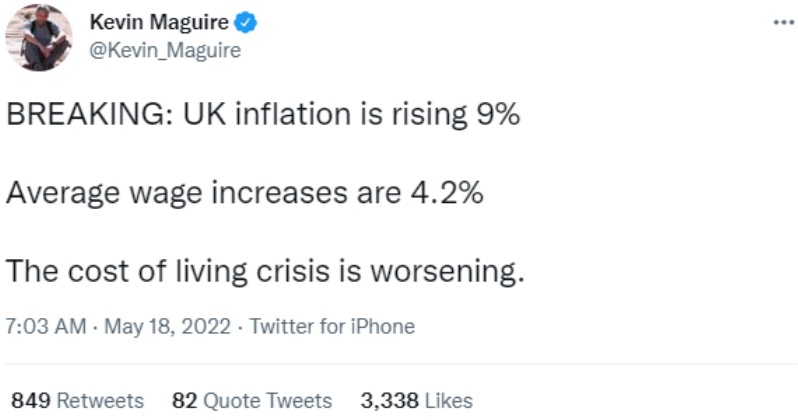


Figure 8: https://twitter.com/Kevin$_{M}aguire/status/1526805742023499776$

Figure 9: https://twitter.com/garth$_{fox}$/$status$/1526809817792356353

Figure 10: https://twitter.com/ChillaxBcn/status/1527023963217567746

3.5.3 Data

Examples of individual tweets

Data Processing:

- Data Scraping using Tweet API (Sarah: Is this bit perhaps mixing up the individual tweet analyses with the news outlet all tweet analyses?) Data Scraping using Tweet API
- Recent tweets from the last 6 - 9 days
- Topic: #inflation
- Accounts studied:* Recent tweets from the last 6 - 9 days
- Topic: #inflation
- Accounts studied:

  @BBCNews (13.9M)

  @MailOnline (2.7M)
- sentiment analysis (R packages) using sentiment dictionary for words representing uncertainty, positiveness, negativeness and neutral.
- sentiment metric for each tweet
- cumulative average metric is calculated for tweets that are responses to one tweet id.

3.5.4 Results

News Outlet Twitter Accounts

Sentiment analysis of individual twitter accounts:

Inflation Tweets

Cumulative average sentiment score of Kevin Maguire and Sky News on #Inflation:

Other data obtained (for future use)

- Recent tweets from @BBCNews and @MailOnline are extracted into 4 csv files (on Google drive)

Tweets	uncertain words per	positivity mean	number	retweets	favourites
Tweets from BBC-News	0.0012113	-0.7165992	245	10760	33596
Tweets to BBCNews	0.0448189	-0.2685468	9081	10760	33596
Tweets from MailOnline	0.0044614	-0.9630435	422	5497	14509
Tweets to MailOnline	0.0385596	-0.2861718	3138	5497	14509

Table 5

tweets at	uncertain words per	positivity mean	replies	retweets	favourites
SkyNews	0.0158730	-0.2481752	126	298	520
Kevin Maguire	0.0594406	-0.2100239	286	849	3338
BeckettUnite	0.0000000	-1.3809524	15	371	918
premnsikka	0.0606061	-0.4347826	33	807	1369
garth fox	0.0566038	-0.4255319	53	716	2472
ChillaxBcn	0.0416667	-0.0800000	24	245	491

Table 6

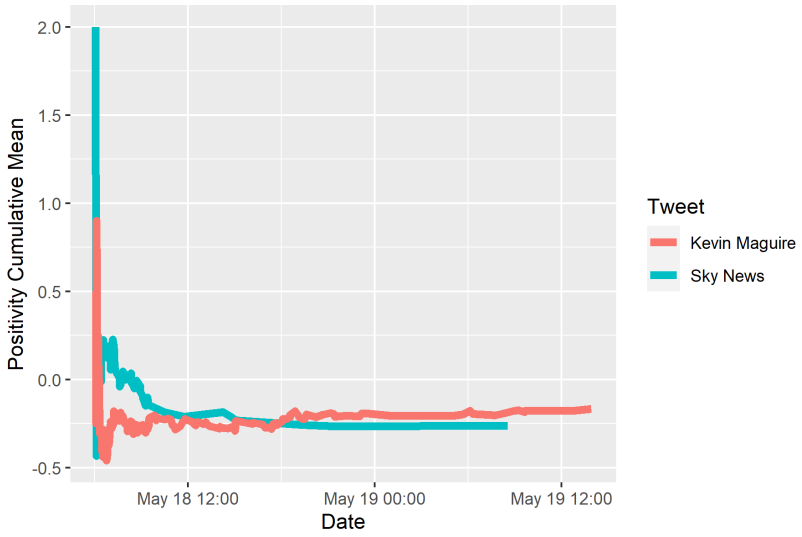


Figure 11

- Twitter emoji data
- Tweets positive, negative and neutral labelled datasets (on Google drive)
- Deep learning sentiment extraction

3.5.5 Future work:

- Apply deep learning on Sentiment analysis: currently some data have been collected, a draft of using pre-trained model is available on Kaggle. The model is only able to distinguish among positive, negative and neutral. Required future work: modify the current dataset and provides labels for words representing uncertainty.
- The measure of spread of tweets are currently based on the number of likes and retweets. Another side could be added is to capture the like and retweet over daily period. For example, capture the new related tweets every 24 hours and measure the number of changes in spread.

3.5.6 Twitter API data instructions:

This section gives a summary about setting up twitter API which allows processing and searching data in large scale.

Figure 12: https://medium.com/@tomyuz/a-sentiment-analysis-approach-to-predicting-stock-returns-d5ca8b75a42

Access data (Essential account) To access the Twitter API, the user need to set up a developer account in: https://developer.twitter.com/

After setting up you developer account, you need to apply to get:

- bearer token
- ACCESS TOKEN
- ACCESS SECRET
- CONSUMER KEY
- CONSUMER SECRET

You only need to use the bearer token and put your bearer token in the code we provided on google drive to pull the data. However at this stage, your account would only allow you to download the latest 6 to 9 days data from Twitter API.

After this step, you only have the essential access to the API. The access level detail can be found here.

Access full data (academic account)

There are two different accounts to apply for, for researchers and students you can go for the academic account.

To have access to the full data, you can apply for a free academic account using this link. The frequency and usage of data guideline are written on the website.

Reference for using Twitter API

The Twitter API v2 endpoints are equipped with a set of parameters called fields, which allows you to select just the data that you want from each of the objects in your endpoint response. https://developer.twitter.com/en/docs/twitter-api/fields

3.5.7 Study Group working notes: (group 3)

Characterising trustworthiness of tweets from news accounts

Plan

- Taking all the tweets from several twitter accounts of news outlets over a set time window: 6-9 days prior to 20th May 2022.

Accounts:

- @BBCNews (13.9M)
- @MailOnline (2.7M)
- @guardiannews (3.7M)
- @Telegraph (3.2M)

- Calculating the amount of uncertainty of all tweets across the time window, for each outlet in turn - Calculating the amount of positive/negative language used in all tweets across the time window, for each outlet in turn - Measuring the amount of engagement these outlets get over the same time window - Looking at the relationship between amount of uncertainty/emotive language for each outlet and engagement with its tweets

Research Questions

- Does the amount of uncertainty/emotive language used in tweets vary between news outlets?
- Does the amount of uncertainty/emotive included in tweets affect the amount of attention/engagement those tweets get?

Looking at twitter

Accessing the twitter API and comparing the promotion(retweets) of different tweets.

Using tweepy to access past week twitter data. Current work: data accessed. need further analysis

Plan:

- eg #gamestock, #eurovision, #elonmusk
- high retweet number
- user id
- text from retweet

- a simple sentiment analysis: positive or negative
- What are the most popular tweets (restricted to the last 6-9 days)
- Who is retweeting them?
- What is the distribution of sentiment along with the retweets?

4 Challenge 2: Communicating Mathematics

4.1 Overview

4.1.1 Why should we communicate mathematics?

Mathematics is hugely important to our lives. It plays a key role in modern technology, and in all aspects of decision making (from households up to government). It is also a great subject in its own right. It can be enjoyed, appreciated, and used by all members of society, and mathematically trained people are of great value in many occupations.

However the positive role that mathematics plays in our society is neither well appreciated or well understood. Maths is often thought of as being useless, boring, scary, hard, and certainly not cool. Sadly, with notable exceptions, this is a view perpetuated in many levels the media. Indeed, during the course of the workshop there was a news item published in many newspapers, that claimed that even *saying* the word mathematics was scary (and it should be replaced by the word numeracy. See Fig. 13.

Equally sad is the way that many mathematicians seem to like to perpetuate the image that mathematics is an elitist subject, and that to use mathematics for applications, somehow tarnishes it. There is a feeling in academia (and sometimes even in the media) that somehow *pure is best!*.

None of this is true! An obvious counter example being the critical role that (often very sophisticated mathematics) played in the fight against COVID-19, and is also playing in the way that we understand, and counteract, climate change. The Google search engine (which all of us use, all the time), mobile phones, and credit cards, all rely for their operation on sophisticated mathematical algorithms. Mathematics is vital both for society in general, and for individuals in that society, to communicate to them as clearly as possible, that mathematics is both fun to do (at all levels, not just maths geeks), and is essential to both modern technology and to the process of making informed decisions based on data and evidence. If we do not do this then not only will the UK be left behind in an increasingly mathematics based technological world (we don;t know what the next technology like Google will be, but we do know that it will be based on mathematics), but individuals, and policy makers will find it increasingly hard to interpret the world that they live in. As an example, see Fig. 15, where an NHS spokesman has clearly come unstuck trying to explain the (perfectly valid!) mathematical model informing the COVID-19 Alert Level.

Figure 13

Figure 14: The newspaper report which came out in the same week as the Study Group

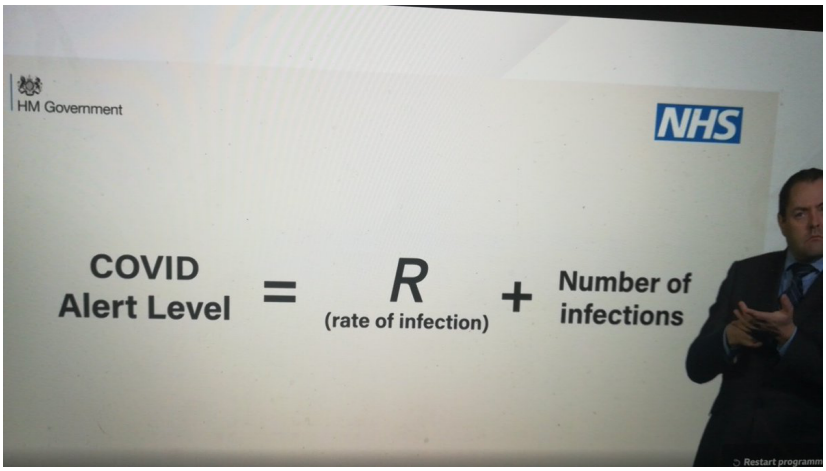


Figure 15: An example of the miscommunication of a mathematical idea (in fact quite a valid one) during the COVID-19 pandemic.

Coronavirus: Why the maths behind 'COVID alert levels' makes no sense

How Number 10 should illustrate its Covid alert formula

4.1.2 Questions to consider

During the study group the working party put together a series of questions which should be addressed both during the week and in this report. The following were considered to be important:

- Q1 How can we encourage and train our colleagues to do public engagement in mathematics
- Q2 What are we trying to do by communicating mathematics
- Q3 What are the possible audiences and what do each know (and when should we start public engagement) in mathematics
- Q4 How do we communicate uncertainty and disagreement.
- Q5 What are good ways to put across the mathematical message (and what is that message).
- Q6 Barriers and challenges (with examples) and how to overcome them!

4.1.3 The purpose of this report

The purpose of the Communicating Mathematics section of the is report is mainly to provide a guide to those wanting to get involved with mathematics communication, and to talk both about the background and the practicalities of doing this. Anyone can ve involved in mathematics communication, from undergraduates, to professors, and professional full time communicators. We hope that the notes provided will be of use to all. The structure of this guide is to address the (so-called) **A,B,C** of mathematics communication identified as follows.

- **A**udience. Who is our intended audience, what is their background, what do we want to say to them, and how should we say it. The first part of the report will look at different audiences and how we can work with each.
- **B**elief. If we (as mathematicians) don't believe in our subject and can express the fact that mathematics is amazing, then no one else will. In this section we will look at the motivation for being a mathematics communicator, and will give examples of good practice. The nice thing is that there are some exceptional examples of good communicators out there (far more than there were ten years ago), and that communicating mathematics is (slowly) becoming more acceptable as something that university based mathematicians should be involved with. But there is still much to be done, and this report will show how this can be possible.
- **C**ontent. What techniques and ideas should we use to communicate mathematics? In this section we will explore what works well, or not, and will give a list of resources that are freely available.

4.2 Audiences

It goes without saying that there is no point of communicating mathematics if there is not an audience to communicate it to. The style, and content of the delivery of any form of mathematics communication, must be carefully tailored to each audience if it is to have maximum impact. It is very important to be sympathetic to your audience and it is very easy to put them off. Above all *do no harm!*. Always be aware of what your audience knows and how you can take them from that to get engaged in the exciting material that you want to convey. Don't think of communicating maths as a process of dumbing down to an audience. More think of it as a way of raising your audience up! Anyone can enjoy mathematics (to quote Nira Chamberlain *you don't need anyone's permission to be a mathematician*), and maths is the only science that anyone can do without needing a laboratory or a field trip.

Having said all of that, mathematics is not always an easy subject to communicate. (How we envy historians that can captivate an audience with tales of sex and violence.) Indeed it is impossible to communicate technical mathematics to a general audience (what primary school child is interested in Sobolev space embeddings for example). So any form of mathematics communication has to make compromises. That does not mean that it is impossible to communicate, it just means that we have think carefully about how we do it. Good methods, which work well for *any* audience, include looking at the creative and discovery aspects of maths (puzzles and games are good here), telling mathematical stories which involve people (a good example being the story behind Fermat's last theorem), and looking at the limitless applications and relevance of mathematics (such as in climate change COVID-19, art, music, voting, etc. etc.).

In the study group we identified the following potential audiences: the (various) media, primary school students, secondary school students and their teachers and parents, the 'general and diverse public', industrialists and policy makers, The general issues concerning, and the possibles approach to each of these, are summarised in the following tables 7,8,9. Later in this report we will expand in more detail abou the various audiences identified.

4.3 Belief

Having looked at our audiences, we will now look at the area of how to motivate ourselves to communicate mathematics, and the reasons behind it. This section may be useful for anyone planning to communicate mathematics, but who needs to convince themselves, or their head of department, to devote tome and resources to doing this.

4.3.1 Why should you do it

Some research has been conducted into the benefits of communicating mathematics to various audiences. This benefit can come both through the communication itself, and also for the training, and self confidence, that it gives to the students and members of staff doing it. The following reports give excellent evidence for getting involved, and of the importance of mathematics to the UK economy:

- Vorderman report
- Positive effects on students

Audience	Aim	Background understanding	Approach
Teachers	Help and enrich answer to question 'when will I ever use this' . Encourage creativity in maths	Technical knowledge but not up to date in ideas and applications (eg. film).	INSET days, AMSP, direct partnership with universities
Policy makers (MPs, civil servants and advisors)	Give rigorous advice (eg. COVID, Climate), lobby	Often arts graduates	Good clear graphical representations, Correct description of uncertainty, Select ctee, PSC, RS scheme, can mathematicians be policy makers
Policy makers (CSA, House of Lords)	Provide scientific evidence, help and be helped	Can be highly numerate	Talk to them .. give examples. Structured pathways or knowledge routes may exist e.g. SPI-M/SAGE for Covid; university-based centres for linking science and policy such as CSaP at Cambridge. Make use of gov's 'Areas of Research Interest' to align with their current interests/needs - this page is regularly updated and a lot of thought goes in to forming these questions.

Table 7: Part 1.

Audience	**Aim**	**Background understanding**	**Approach**
Journalists/media (general)	They are our link to the public, Give clear evidence. Show that maths is a creative subject	Can be very limited. Looking for an article people will read and done to a deadline. Based on news event. May focus on a worse case scenario which makes a headline. May mislead	SMC, University press office, Correct description of uncertainty, expand understanding on when it is good to give a good maths story, Give them a good hook! Good human stories (diverse), Try not to get into a fight, give good clear stories, fun maths
Journalists/media (science)	Link to the public, Give clear evidence	Numerate/trained to look at the science	Build a relationship, Twitter
Primary	Inspire, prevent a bad attitude forming. Offer opportunities to learn about maths outside of the rigid ciriculum. Discuss maths anxiety	Very little. May learn new stuff online eg. Tik Tok	Going into the school, Tik Tok, NRICH, peer to peer (cf. Bath Taps). Showing we are human and making mistakes too.

Table 8: Part 2.

Audience	**Aim**	**Background understanding**	**Approach**
Secondary	Inspire to like maths and be aware of the opportunities. Creativity in maths. Discuss maths anxiety	Narrow perception of what maths can be used for eg. numeracy. Dont appreciate it is important in eg. art. Learn through school but also online eg. Tik Tok	Online eg. YouTube and Tik Tok, maths clubs, Maths inspiration, PLUS, UKMT, (RI) Maths masterclasses (for motivated students), directly going into schools, books. Showing that we are human and make mistakes too
Parents	Help to understand what their children are learning and opportunities for them. Motivating theory children 'why are we doing this'	Completely general	Books (eg. Rob Eastaway), YouTube
Diverse	Challenge the stereotype!!, Show maths is not just white men. Girls are great at maths!!! Maths is creative	Same as all but may be distorted by the public perception of what mathematicians are	Show maths is done everywhere eg. calculus in India, good role models!
General public	Show maths is everywhere and is both relevant and fun. Everyone needs to use maths in some way	Confuse maths and numeracy	Online, Science Fairs, Museums, MWUK and Maths City (Leeds), Science Centres eg. we the curious, Books, public lectures
Industry and business	Give clear advice. Show what new ideas are out there	May be high but not necessarily	INI, Study groups, KTN, HIMR, ...

Table 9: Part 3.

- Education endowment foundation (improving maths education in 7-14 year olds)
- The Philip Bond Report 'The Era of Mathematics'
- The 'Leeds Report' on impact of fluid mechanics

4.3.2 Star performers

If you want to be inspired, here are some great mathematics communicators. See how many there are! Most of them have a strong presence on social media. Do check this out and learn from them.

- Hannah Fry (popular books, media and TV, policy)
- Bobby Seagull (TV, maths anxiety)
- David Spiegelhalter (statistics)
- Nira Chamberlain (former IMA president, diversity)
- Matt Parker (author, Numberphile, stand up maths)
- Ben Sparks (Numberphile, maths and music, Maths Jam)
- Kit Yates (author, policy, media)
- Rob Eastaway (Maths Inspiration, parents)
- Katie Steckles (popular pure)
- Tom Crawford (popular applied)
- Marcus du Sautoy (popular books, talks, and TV, pure)
- Simon Singh (popular, policy)
- Steven Strogatz (popular books on applied, media)
- Colin Wright (popular talks, fantastic juggler)
- Martin Gardner (popular books)
- Ian Stewart (popular books, high level)
- Alex Bellos (author, puzzles, media)
- Numberphile (popular, mainly pure)

- Duncan Robertson (policy, OR)
- Christina Pagel (policy, OR)
- Chris Budd (popular applied, policy, industrial)
- Tadashi Tokieda (maths of toys)
- James Grime (cryptography, maths museums)

There are many other examples of great practice, and apologies to those not listed above.

4.3.3 More general examples of good practice

Here are some other excellent examples of good practice at a more institutional level. The website of all of these have lots of useful resources.

- Royal Institution (especially the Mathematics Masterclasses) RI Masterclasses
- HE-STEM Guide to good practice
- Oxford Mathematical Institute Outreach
- Oxford Maths Festival and Public Lectures
- Leeds Maths City
- US National Museum of Mathematics (incl online activities)
- The United Kingdom Mathematics Trust which organises mathematics competitions in the UK.
- Outreach at the Institut Poincare in Paris (French and English language)
- Imaginary
- Bath Communicating Mathematics Course for final year undergraduates.
- Data journalism e.g. FT
- modelling e.g. Full Fact article

4.4 Content

Having convinced yourself and others that you want to do some mathematics communication, here are some general ideas and resources that you may find useful for communicating mathematics, training in mathematics communication, and support for the process of mathematics communication.

4.4.1 Websites for content and training

- Maths Careers website
- UKMT
- AMSP
- Training in public engagement: Royal Society Courses
- SMC
- Nrich

4.4.2 Organisations that facilitate collaboration between universities and industry

- Knowledge Transfer Network
- Newton Gateway to Mathematics
- Isaac Newton Institute
- ICMS
- The Alan Turing Institute
- V-KEMS

4.4.3 Other resources

- NRICH - Mathematics Resources for Teachers, Parents and Students to Enrich Learning (maths.org)
- Plus magazine! | plus.maths.org
- Secondary mathematics resource packages | STEM

- Maths Workshops for Secondary Schools - Creative Maths Workshops for KS3 / KS4 (ascreatives.com) Welcome | Think Maths
- Talking Maths in Public
- Communicating Mathematics in the Media: A Guide
- Mathematics Matters
- Do The Maths Thing

4.5 Appendix: Detailed advice on working with different audiences

In this Appendix we will look in some detail at the techniques, and resources, useful for communicating with the various audiences identified earlier.

4.5.1 Possibly awkward audiences: thoughts from/to someone new to science/maths communication for potentially contentious issues

- Social media tension between popularity and objectivity (incentive to get more views from sensationalist content)
- Relationships between scientist and journalists are important (eg on Twitter; reputations for reliability take a long time to build and a short time to lose
- Show your workings. State where you obtain your data/ show your methods. It adds to legitimacy.
- A picture says a thousand words. Visualization is important.
- Read widely from reputable sources. Mis-/dis-information can be an issue and it is imporatant to either avoid amplifying or to actively refute.
- Some media outlets are less interested in the truth and more interested in making news through amplifying disagreements. Be selective with which outlets to engage with.
- Strength of analysis comes from engaging with a diversity of people from other disciplines. Twitter is a good place for this.

4.5.2 Primary schools: students and teachers

Primary schools are a HUGE audience. All children have to go to primary school, and all have to learn maths. Often their teachers have not studied mathematics beyond GCSE. Studies have noted that children's mathematics career is largely determined by age 11 (see the Vorderman report described above), making maths communication prior to this in primary school particularly important. Teachers generally do not study maths at tertiary level, with only 2% of those taking primary PGCE having degrees in a STEM discipline (Vorderman report). *A consequence of the lack of mathematics background is that many primary school teachers do not have the confidence to evaluate, and at times reject, resources, methods and advice, often from non-statutory bodies, commercial organisations and professional associations.*

The workshop identified several reports promoting changes to maths education in the UK that have relevance for the delivery of maths communication within Primary Schools.

Ofsted reccomendations for maths education include: Mathematics: made to measure

- ...the most able pupils in nearly a quarter of primary schools were insufficiently challenged, often because they were set very similar work to their middle-attaining peers before moving to extension tasks
- Still too little 'using and applying mathematics'
- Schools should increase the emphasis on problem solving across the mathematics curriculum

  And from the Education Endowement Foundation for use of resources:
- "Use stories and problems to help pupils understand mathematics"
- "Use tasks to build conceptual knowledge in tandem with procedural knowledge"

  Ideas from best-practice maths education may be useful, for e.g. from The Teacher's Role in Classroom Discourse: A Review of Recent Research Into Mathematics Classrooms
- Create environment conducive to sharing
- Listen attentively and help guide ideas to solutions in real time

  A report by the Fair Education Alliance suggests "The UK remains one of the least socially mobile economies in the developed world." This report contains case studies of various primary schools and compares practices between those that are and are not closing attainment gaps, including:

- Raising the profile of maths, with opportunities for maths across subjects purposefully identified
- Providing 'maths week' and/or 'enterprise week' across the school to develop maths skills and financial literacy

4.5.3 Primary schools: parents

At a primary level parents have a much larger impact on their children's education than at secondary schools.

Research has shown that this element of home learning makes a huge difference to a child's education. However, changes in arithmetic methods have left many parents unable to help their children. (Vorderman report)

Amongst primary school parents in England "Findings revealed some specific negative effects of school-centered approaches, and suggested that school-centered approaches may in fact restrict parents' understanding of how they can support mathematics learning in the home." (Jay et al. 2018).

"Previous research suggests that, while there are high correlations between parental involvement and positive student outcomes, it can be difficult to raise student achievement via parental involvement interventions. We suggest that part of the reason for this, at least in relation to mathematics, is that parents experience considerable difficulties in negotiating school-centered definitions of and approaches to mathematics....As parents became more confident in their own analysis of the mathematics in everyday family life, they developed new strategies for sharing this mathematical thinking and awareness with their children." (Jay et al. 2017)

[Jay 2017] Jay, Tim, Jo Rose, and Ben Simmons. "Finding" Mathematics": Parents Questioning School-Centered Approaches to Involvement in Children's Mathematics Learning." School Community Journal 27.1 (2017): 201-230.

[Jay 2018] Jay, Tim, Jo Rose, and Ben Simmons. "Why is parental involvement in children's mathematics learning hard? Parental perspectives on their role supporting children's learning." Sage Open 8.2 (2018): 2158244018775466.

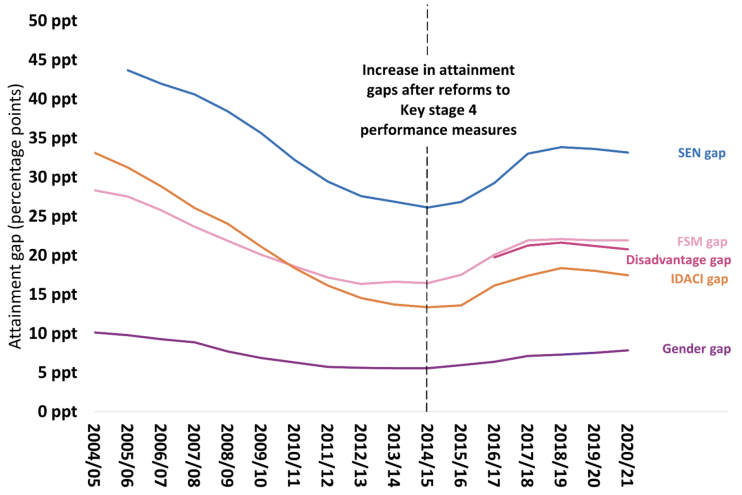
4.5.4 Audiences with diversity

Mathematics is for everyone, and it is important that mathematics addresses, and celebrates, diversity. However, there are persisting issues of representation within mathematics which can make it less attractive to a diverse audience (where we think of diversity in terms of gender, race, disability, sexual orientation, social background etc.)than it should be.

The Institute of Fiscal Studies reports on the gender gap in maths (and physics) at A-level.

General attainment gaps in Maths and English by gender, SEN status, deprivation etc.

Figure 5: Out of all attainment gaps at Level 2 by age 19, the widest is between those with and without Special Educational Needs (SEN).



Footnotes

1. Figures for disadvantage only available from 2016/17 onwards.
2. See accompanying methodology for definitions of characteristics.
3. Figures for pupil characteristics do not include those in independent schools.
4. Attainment gaps refer to the difference in attainment between one characteristic group and another. 1) Special Educational Need (SEN) gap: between those with and without SEN, with non-SEN individuals typically having higher attainment; 2) Free School Meal (FSM) gap: between those eligible and not eligible for FSM, with those not eligible for FSM typically having higher attainment; 3) Disadvantage gap: between those deemed disadvantaged (see methodology) and those not disadvantaged, with those not disadvantaged typically having higher attainment; 4) Income Deprivation Affecting Children Index (IDACI) gap: between the 25% most deprived and the 25% least deprived, with the 25% least deprived typically having higher attainment; 5) Gender gap: between males and females, with females typically having higher attainment.

Figure 16

Recent HESA statistics on the proportion of undergraduate students within the UK suggest that in the 2019/2019 academic year 37% of incoming students in mathematical science degrees were female [STEMstats].

Advancing Women in Mathematics: Good Practice in UK University Departments

Attrition of women in maths has been attributed to various factors including perceived lack of

diversity of careers involving maths (Piatek-Jimenez 2015).

BAME groups are also typically poorly represented. "Our reports show that Black people are more likely to drop out of science at all points of the career path. It is time that the whole science community comes together to find out why and put it right. (Sir Adrian Smith)

LGBTQ+ mathematical scientists are more likely to experience barriers in their careers [RSS-diversity].

In the US minority-language groups are underrepresented in mathematical fields [Moschkovitch 2002].

One potential mechanism for improving diversity is ensuring minority groups within mathematics have a sense of belonging. This has been shown to be relevant for maintaining undergraduate women's interest in STEM subjects [Thoman 2014]. In practice this could involve striving to include personal stories from mathematicians with diverse backgrounds when communicating mathematics (as also mentioned by Rachel Thomas).

A recent joint RSS/IMA/LMS response to a diversity in STEM consultation [RSSdiversity] made the following recommendations:

- Ensure that education in mathematics and statistics represents and reflects the interests of a broad part of society and that all students are encouraged to study mathematics and statistics by: bringing back an AS-Level qualification in maths to encourage more students to ensure that STEM professions remain an attractive area for diverse individuals to go in to by identifying measures to tackle bullying and harassment.
- Develop new educational and training routes to increase participation in data science and AI fields by students from lower socioeconomic backgrounds in consultation with relevant industries.
- Develop meaningful regulatory frameworks to ensure that algorithms are not violating people's rights under the equality act, GDPR, consumer protection law or anti-competition law.
- EPSRC/UKRI should introduce mid-career acceleration grants which are open to individuals who are no longer eligible for the New Investigator Award (NIA) scheme, and who have not recently applied for or held UKRI funding.
- Work with professional societies to choose benchmark professions within STEM in which to track progress. For example, statisticians, data roles, engineering roles, accountancy roles, developer roles

Other inclusivity considerations:

- Brzostek-Pawłowska (2019) [Brzostek-Pawłowska 2019] discuss the use of interactive multimedia solutions to communicate maths to students with visual impairments.
- When undertaking maths communiation in schools, consider the needs of minority-language speakers. This may include ensuring everyone has the relevant common vocabulary, being careful to explain use of terms that may have multiple meanings or different meanings in a mathematical context [see Moschkovich 2002].
- Higher education students with dyslexia at higher risk of maths anxiety [Jordan 2014].

4.5.5 Secondary schools; background

Maths varies a great deal in secondary schools, from KS3 maths where many attitudes to maths are set in stone, to GCSE maths which is often the final time when many students study mathematics, to A level maths where we are training the mathematicians, engineers, scientists, and many others, for the future. (Note that only in England and Wales, is it normal to drop mathematics at the age of 16, most other countries continue teaching maths to **all** students up to the age of 18.)

Why should we put particular emphasis on communicating mathematics to secondary school students?

A survey of teachers by Pearson found the thing they felt would help them the most to inspire students about the power of maths is more positivity about maths in popular culture. There are a multitude of factors that influence ATM including achievement, gender, age, socio economic status and linguistic background. [2]

Achievement

Study by Pepin [1] comparative analysis of secondary pupils' attitudes towards maths in Norway and England:

- Emphasis on the utilitarian aspect of mathematics, in the sense of using it as a means to qualify for a particular job,

  'You get to learn new skills and it will help you later on in life … because algebra etc. can help you in jobs such as an accountant…" (EY7-SO) '… I struggle with any work… my dream is to become a police officer and you need to have a GCSE in maths." (EY9-JF) This

was more evident in English pupils' comments than in Norwegian pupils' comments. In Norway mathematical studies are compulsory up until the age of 18. Trends in International Mathematics and Science Study TIMSS (2011) [3] found 85 per cent 14-15 year old students internationally (belonging to 63 different countries) believe that maths is useful in their daily lives and in securing a good job in the future. The students who valued maths had the highest average achievement, followed by the ones who somewhat valued the subject. The students who did not consider Maths to be important (15

- Approximately half of the pupils, in particular those who seemed to succeed in mathematics (according to their comments), talked about mathematics as a 'challenging', 'interesting' but 'hard' subject to learn. Others characterised it as 'boring', 'non-creative' and 'confusing'. '… it is boring and it does not allow you to be creative. … ' (EY11)
- English pupils perceived the nature of mathematics more rigidly as 'getting the right answer', and where little creativity is encouraged. "With maths, the answer is either right or wrong, whereas with other subjects like English and History, there are many different answers." (EY11) "… it is not an interesting subject. There is nothing fun towards this subject and a lot of it just feels like you're doing the same thing all the time." (EY11) "… once you learn how to work out an equation or formula, you keep repeating the same method and there is always one correct answer. …" (EY11)
- Pupils wanted to work 'differently', in a problem solving way and with more open questions. "I like problem solving. I think it is fun. I like to think and reflect…" (NY6)
- In both countries' little practical investigative work was done, but when it was done, pupils enjoyed this aspect, and especially enjoyed the opportunity to work in groups in order to understand the mathematics better.

  "It is not as much fun and enjoyable as other subjects … I don't learn by being shown but I do learn by doing and playing games about different types of things. I also like doing presentations…" (EY7)

  ''… As I sit next to my friend I feel more relaxed in a new set and know that she will also help if I ever don't understand." (EY11)
- Pupils, mainly in England, talked about their attitude towards mathematics being influenced by their family and parents helping them, or the primary school experiences giving them the confidence to have a positive attitude. "I learnt maths when I was little. My mum learnt me maths … and now I am great at maths." (EY7) "My dad is excellent at maths and helps me … Also in my primary we did lots of maths…" (EY7)
- It seemed that the assessment system played a crucial role in pupils' perceptions of what mathematics is and how to become a 'proficient' mathematics learner. For example,

in both countries, but more in England, pupils practice on examination questions several months before the examination. This means that nearly all curriculum teaching is suspended, and pupils and teachers go over past examination papers-'teaching to the test'. Examinations appear to define whether a pupil is 'good at maths' or not. Research suggests a positive relationship between academic attainment and attitude towards Maths [2].

Gender

There has been a fairly steady increase over the last 25 years in the percentage of students taking A level mathematics who are females, from about 30 per cent in the 1980s to about 40 per cent in 2015 (JCQ, 2016b). Perhaps this has something to do with mathematics now having a more prominent exchange value, portrayed as a door opener to many possibilities in life (Taylor, 2014). However, girls, regardless of mathematics aspirations, were less likely than boys to be encouraged by their families and others within their social circles to study mathematics post-16. [7]

- Maths is perceived to be a masculine and male dominated field (Ernest, 2004) [5]
- Boys exhibit a high level of self-concept regarding their mathematical abilities and consider themselves more able than girls (Ireson, 2001). [6]

Attainment

- TIMSS (2019) gender difference in average attainment in mathematics in England not statistically significant in age range 9-14.
- PISA study 2018 looking at the attainment of 15 year olds found In England, boys performed significantly better than girls. This was also the case for the OECD average. This year PISA will focus on mathematics. PISA 2022: Mathematics Framework (oecd.org)

4.5.6 Secondary schools; outreach:

There is significant current effort in providing mathematical outreach at a secondary level, for example by masterclasses, open days, science fairs, and maths circles. Much of this is done by universities, partly for altruistic reasons, and also because they recognise that they need to encourage future undergraduates. The various university outreach activities can be categorised as:

1. Utilitarian initiatives - Courses to help prepare for admission tests such as STEP, MAT, TMUA. https://amsp.org.uk/students/university-admission-tests/step-mat-tmua
2. Recruitment focused activities-e.g. Maths taster days.
3. Activities to promote maths in general, whether that is to showcase maths as fun or illustrate its impact on society.
4. Activities based around linking undergraduates with secondary school students, both to give the school students positive role models and also (as in the University of Bath 'Communicating Maths' scheme, or the various 'Undergraduate Ambassador schemes) to provide valuable training for undergraduates in communication skills and/or to give them some insight into teaching as a career.

These activities are delivered by academic staff, students (both undergraduate and postgraduate), or outreach officers employed specifically for the maths communication skills.

- Maths taster days (most targeted at Year 12 but many universities offering taster days for Yr 6-11)
- Women in maths taster days
- Science Festivals: Maths: Elements of Modern Science - Edinburgh Science (everyoners2.com) Bath Taps into Science, British Science Festival , New Scientist Live, Big Bang Fair.
- Black Mathematician event (UCL) The first Black Mathematician Month outreach event - Chalkdust (chalkdustmagazine.com)
- Popular Maths lectures Birmingham Popular Maths Lecture - University of Birmingham
- Royal Institution Masterclasses: About Masterclasses | Royal Institution (rigb.org)
- Fun Maths Roadshow FunMathsRoadshow (livmathssoc.org.uk)

4.5.7 Industry and Business

- Collaboration between industry and universities is one of the principal routes for knowledge exchange in both directions (see the **Bond Review** above). The collaboration might take the form of joint projects, consultancy, as well as industry sponsorship of doctoral/masters students or industry placement of interns.

- When discussing collaboration with industry partners and effective Knowledge Exchange, it is important to understand and incorporate their objectives. While some firms seek assistance with isolated specific problems, others prefer long-term relationships with leading research groups. The latter might wish to broaden their horizons, improve access to candidates, advertise themselves, or in fact all of these.
- Do not underestimate either the expertise or the domain knowledge of industrial research groups. Especially in fields where secrecy and NDAs are the norm, such as parts of finance, energy, commercial, or the security sector, firms might conduct cutting-edge research for decades, without publishing anything at all.
- To facilitate collaboration between universities and industry, CASE doctoral studentships are available from the Engineering and Physical Sciences Research Council (EPSRC) grants.
- Many industries hire interns or placement students. Examples include the financial, environmental, energy, insurance, and gaming sectors. Quantitative analytics groups within the larger banks, for instance, actively seek knowledge transfer from universities, relying on interns to explore ideas that seem to have potential but where there is high uncertainty about the outcome.
- (Virtual) Study Groups (such as those organised by V-KEMS) are an effective way to make contacts between universities and industry, to solve problems, and to provide training on all sides: See Study Groups with Industry: What is the Value?.

4.5.8 Policy Makers

- Publication of mathematical models and SPI-M minutes
- Example of House of Commons library briefings
- Link to trustworthy communication (Group 1)

4.5.9 The IMA guide to explaining mathematical modelling:

This is useful if you need to describe modelling to any audience, whether it is industry, policy makers, or the general public

Prepared for the IMA organised meeting of the Parliamentary and Scientific Committee.

Mathematical models and algorithms:

- are currently used to great effect to drive technology, to make evidenced decisions, and to improve people's lives
- examples include: energy, medical imaging, Google, mobile phones, COVID-19, weather/climate prediction, insurance, transport, etc etc
- are normally carefully designed, and tested on data.
- need to be used for what they are designed for
- need careful communication when used for decisions affecting the public
- need to be applied with careful judgement, especially when used to make decisions
- all have a level of assumptions and uncertainty. Understanding and quantifying this is an essential part of the modelling process.
- for all the benefits and limitations of mathematical or statistical models outlined, not to employ them is at best educated (and at worst uneducated) guesswork.

Understanding model limitations:

- E.g., with reference to COVID models: Wrong but Useful — What Covid-19 Epidemiologic Models Can and Cannot Tell Us
- E.g., Demystifying modeling: How quantitative models can—and can't—explain the world

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5 Challenge 3: Misinformation

5.1 Misinformation Objectives

- Define misinformation and consider usable terminology for subsequent discussions.
- Identify desirable publication protocols and salient features of reliable communications.
- Consider strategies for assessing cases presented to the Office for Statistical Regulation (OSR)
- Potential follow on investigations: Identify key words for assessment of validity.

5.2 Background Information

Annual Review of UK Statistics Authority Casework 2020/21 Published: 30 September 2021 Last updated:5 October 2021

In the period 1 April 2020 to 31 March 2021 the Authority considered 323 pieces of case-work. Nearly three times the number in the previous year (109 cases).

Health and Social Care made up 72% of all cases, driven by the COVID-19 pandemic.

Internally-generated casework accounted for 16%, a smaller proportion than in 2019/20.

76% of cases looked into this year were related to the pandemic in some form.

48% of cases related to quality, reliability and trustworthiness of statistics. The first time this had been the most common category.

The average (median) time taken from opening to closing a case was 10 days (mean 15 days). Compared with 13 (median) and 20 days (mean) in 2019/20.

Resources:

The ONS interventions policy provides more details on their role in making public interventions on the use of statistics.

In October 2020, the ONS started publishing quarterly management information related to their Casework.

They also produce an annual summary of casework which provides details of the volume and types of cases looked at.

How OSR secures change, Ed Humpherson, Director General for Regulation

Communication, David Spiegelhalter

Defining Ground Truth, Ed Humpherson

5.3 Definition: Misinformation vs Disinformation

The following definition is adopted in this section: Misinformation is false, misleading, or out-of-context content shared without an intent to deceive whereas disinformation is purposefully false or misleading content shared with an intent to deceive and cause harm.

5.4 Establishing protocols for assessment of information

Can we distinguish between misleading uses of statistics, data and evidence vs legitimate alternative interpretations of the same underlying evidence? Also, can we assess prior cases and categorise features of misleading and non misleading cases thus ascertain a grading system to define levels of 'offense'?

It is imperative that reported methodologies are transparent and necessary data is made available to independently verify claims. The Code of practice for statistics ed 2.1 Revised 5th May 2022 highlights the need for critical thinking skills and offers three factors for assessment of information:

- Trustworthiness (truthful, impartial and independent)
- Quality
- Value

Commonly abbreviated to TQV and used as an assessment protocol. More detailed advice on application of TQV when conducting an evaluation is given in The Magenta Book, HM Treasury guidance on what to consider when designing an evaluation. Advise is structured in the use, design and impact of evaluation with emphasis on transparency and communication of information in a useable format.

A culture of evaluation supports effective policy and relies on openness: being open to learning what works and what does not, as well as open about the use of evaluation and releasing information in an orderly way so others can use it:

For example, publish information about the evaluation ahead of doing it and publish the results of all evaluations in a managed way including the data and methods employed so others can scrutinise and replicate the analysis. The Trustworthiness pillar supports openness for individuals and organisations giving confidence in the people and organisations that produce statistics and data. Trustworthiness results when the people, systems and processes within organisations enable and support the production of reliable and repeatable data and analysis. This will come from the organisations being well led, well managed and open, and the people who work there being impartial as well as skilled in what they do. Showing you are trustworthy means being truthful, impartial, and independent, above all free from vested interests.

Information is shared responsibly and with integrity, being open and transparent about your decisions, plans and progress. Further, other people's information is dealt with ethically and securely. With data managed in ways that are consistent with relevant legislation, and serve the public good.

Design choices lie at the heart of excellent evaluation. High-quality evaluation happens when the evaluation question is well defined, the design is proportionate for its purpose and the scale of the policy and the right data and robust methods are selected, tested, and explained The Quality pillar can help you in making these design choices.

Quality implies statistics meet their intended uses, are based on suitable data and methods, and are not materially misleading. Quality requires skilled professional judgement about collecting, preparing, analysing, and publishing statistics and data in ways that meet the needs of people who want to use the analysis. Organisations should communicate the quality of the data and methods chosen to its audiences. A commitment to quality is shown by considering and describing how the evaluation sources and selects data and chooses and tests methods to ensure their suitability. It is reflected in seeking expert review at key stages and by informing users about the quality and limitations of the evaluation.

Impactful evaluation demonstrates a clear basis for the evaluation informed by stakeholder insight, determines benefit of a policy and ensures findings are clearly and accessibly communicated with the audiences in mind.

Value means that the analysis is useful, easy to access, relevant, and supports understanding of important issues by effectively communicating evidence as required by various audiences. Users and the intended use should be at the centre of the evaluation, by understanding the

research question and acting on the insight.

5.4.1 Identifying trustworthy information

What key elements indicate validity? Presenting truthful alternatives rather than a persuasive argument. How to educate, without controlling, strong priors?

Can we quantify evidence? eg. give probabilistic values to phrases and sources?

We can quantify how good one explanation is vs another. What we cannot do is say what the truth is as that would require sifting through all possible explanations. Therefore finding the best explanation requires the subjective choice of choosing a set of possible alternatives. There is no strictly objective method of finding the truth although we may be able to find better explanations. However, unless there is a finite set to choose from, we fundamentally cannot know if we have the right answer (Burnham and Anderson, 2002)

5.4.2 Judging misleadingness

Misleading' is used to cover a wide range of situations. Sometimes, the judgement we are being asked to make revolves around the merits of the argument that the user is making, rather than the use of statistics in itself.

"We are concerned when, on a question of significant public interest, the way statistics are used is likely to leave audiences believing something which the relevant statistical evidence would not support." https://osr.statisticsauthority.gov.uk/publication/misleadingness-a-short-thinkpiece/

"To ensure users can confidently make decisions about the statistics that are presented to them, using them without question to access what they require and need".

Three potential approaches to judging misleadingness:

1. **Materiality and intention** – an approach which focuses on the significance of the statement being made. What were the intentions of the speaker?
2. **Audience** – an approach which focuses on audience understanding. Were the audience misled about what the statistics were telling them?

3. **Case-based** – an approach which focuses on particular features of the presentation of statistics. Is the style of presentation unclear and likely to mislead?

Improving statistical literacy for both writer and reader is imperative to ensure each has the necessary skills to assess the validity of publications. An initial assessment might begin with asking the right questions, for example,Does it look right, is it an implausible number? If it's unusual it could be wrong, what's behind the surprise? What exactly are we measuring, and why? Where do the data come from, what is the backstory? How are the statistics calculated and is the source reputable? Is the working shown? Only compare the comparable, be mindful of changes in definitions and measurement scales. Scrutinise associations, is a causal relationship realistic?

Understanding the assumptions is also important, and the assumed precision. Likewise the presentation, good use of visuals helps convey meaning and should never cause confusion or misrepresentation

5.5 Towards protocols for judging validity

Key factors, TQV, in assessment of information taken directly from the statistics code of practice and the magenta book. Is the information from a **T**rustworthy source of good **Q**uality and does it add public **V**alue?

Onora O'Neill (2006) defined intelligent transparency against four essential criteria:

- Accessibility
- Assessability
- Useability
- Intelligibility

Assessability is particularly important for evaluating the validity.

5.5.1 Avoiding misleading statements:

Summarising and communicating in a non-manipulative way is essential whether that's verbal or visual communication. Informing not influencing attitudes, emotions or attempting to

convince an audience of a particular perspective. To present the facts and be as truthful as possible. Not always a balanced argument if evidence not balanced but a fair representation of the facts. This may be easier said than done. Babbage and co on setting up the Royal Statistical Society (1834) had this goal, facts only; figures and tables no personal or biased opinions. Ultimately, context is needed to identify latent features, the facts without conjecture convey only a part of the picture (Spiegelhalter).

There are many classic errors made in communicating statistics, such as implying an observed association is evidence of a specific cause rather than potential confounding. Similarly, although there are many claims that things are biased, the technical definition, of a difference between the expected value of an estimator and the true value of a parameter is important.

5.6 Increasing public engagement and Interest

OSR has seen a rise in caseload over the past two years from approximately 150 to 300 per annum fuelled by pandemic bombardment of both data and opinion. Also huge increase in reporting across society on widening number of social platforms. How can measures akin to the rigours of academic publication be introduced without taking away the dynamic discussion or narrowing participation?

5.6.1 Public sources defining misinformation

1. The online information environment: "Within this report, ‘scientific misinformation’ is defined as information which is presented as factually true but directly counters, or is refuted by, established scientific consensus. This usage includes concepts such as ‘disinformation’ which relates to the deliberate sharing of misinformation content." This view, of course, is based on the assumption that established scientific consensus as the truth.
2. FUN-MOOC on Critical thinking: data and fallacies
3. Turing programme on Understanding vulnerability to online misinformation

5.6.2 UK Government’s Online Safety bill

From UK Goverments Fact-Sheet "The duty of care will require platforms to have robust and proportionate measures to deal with harms that could cause significant physical or psycho-

logical harm to children, such as misinformation and disinformation about vaccines. Platforms will also need to address in their terms of service how they will treat named categories of content which are harmful to adults, likely to include disinformation."

This will mean:

- all companies will need to remove illegal disinformation, for example where this contains direct incitement to violence
- services accessed by children will need to protect underage users from harmful disinformation
- services with the largest audiences and a range of high risk features (Category 1 services) will be required to set out clear policies on harmful disinformation accessed by adults
- The regulatory framework will also include additional measures to address disinformation, including provisions to boost audience resilience through empowering users with the critical thinking skills they need to spot online falsehoods, giving Ofcom the tools it needs to understand how effectively false information is being addressed through transparency reports, and supporting research on misinformation and disinformation.

5.6.3 How social media platforms define and deal with misinformation

It could be argued this is not their role, additionally this power could be open to abuse. Meta have a false news policy but no discernible attempt to clearly define 'false news' which is not generally removed, but might be 'ranked lower' on a newsfeed. Fact checking is left to the "community and third party" so publication will not be prevented all together. There are some sanctions in that 'Repeat offenders' may have their access removed. Policies exist but are not necessarily preventive.

Working to Stop Misinformation and False News

About fact-checking on Facebook

How we address misinformation on Twitter

COVID-19 misleading information policy

Synthetic and manipulated media policy

'Misleading media' is defined on Twitter as 'synthetic, manipulated, or out-of-context media that may deceive or confuse people and lead to harm' Factors leading to removal of misleading media include:

- media that is significantly and deceptively altered, manipulated, or fabricated,
- media that is shared in a deceptive manner or with false context
- media likely to result in widespread confusion on public issues, impact public safety, or cause serious harm

Although many misleading items are permitted in the absence of other policy violations, the following are generally not in violation of this policy:

- Memes or satire, provided these do not cause significant confusion about the authenticity of the media;
- Animations, illustrations, and cartoons, provided these do not cause significant confusion about the authenticity of the media.
- Commentary, reviews, opinions, and/or reactions. Sharing media with edits that only add commentary, reviews, opinions, or reactions allows for further debate and discourse relating to various issues and are not in violation of this policy.
- Counterspeech. We allow for direct responses to misleading information which seek to undermine its impact by correcting the record, amplifying credible information, and educating the wider community about the prevalence and dynamics of misleading information.
- Doctored or fake Tweets, social media posts, or chat messages

EU law attempts to define misinformation in The perils of legally defining disinformation as have individual nations. *"When the definition of disinformation is explicitly discussed, the general consensus seems to be that there is no clear, uniform or legal definition ("Joint Declaration on Freedom of Expression", 2020; Tambini, 2020; Van Hoboken et al., 2019; Nyakas et al., 2018)."*

'Misinformation is when false information is shared, but no harm is meant. Dis-information is when false information is knowingly shared to cause harm. Mal-information is when genuine information is shared to cause harm, often by moving information designed to stay private into the public sphere' (Wardle & Derakhshan, 2017, p. 20

EU High Level Expert Group Definition *'false, inaccurate, or misleading information designed, presented and promoted to intentionally cause public harm or for profit' (HLEG, 2018, p. 10)*

European Comission Definition *'verifiably false or misleading information that is created, presented and disseminated for economic gain or to intentionally deceive the public, and may cause public harm' which is understood to be 'threats to democratic political and policymaking processes as well as public goods such as the protection of EU citizens' health, the environment or security' (2018a, s. 2.1).*

Lithuania has an explicit statuatory prohibition on disinformation, defined as: *"intentionally disseminated false information' (Art. 2). As such, this aligns with Wardle and Derakhshan's definition, in that the definition contains the elements that (a) the information must be false, (b) there must be a specific intention; and (c) causes certain harms. However, it is limited to causing harm to a specific person, and does not include public harm; while there is no requirement of economic gain (as envisaged in the EC's definition). Further, the focus is on the dissemination of disinformation, and not the creation."*

The four international special mandates on freedom of expression have stated that laws containing prohibitions on dissemination of 'false news', which are 'vague and ambiguous', are 'incompatible' with international standards on freedom of expression, and 'should be abolished' (Joint Declaration, 2020, s. 2(a

UN Special Rapporteur on freedom of expression has emphasised how the concept of disinformation is an 'extraordinarily elusive concept to define in law', and susceptible to providing executive authorities with 'excessive discretion to determine what is disinformation, what is a mistake, what is truth' ("Joint Declaration on Freedom of Expression", 2020, para. 42)As such, the penalisation of disinformation is 'disproportionate' under international human rights law ("Joint Declaration on Freedom of Expression", 2020, para. 42). Further, the UN Human Rights Committee has found that prosecution for the 'crime of publication of false news' on the ground that the news was false, is in 'clear violation' of the right to freedom of expression (Human Rights Committee, 1999, para. 24).

5.6.4 OSR Policy on transparency

"We monitor the use of data and investigate concerns where we see unpublished figures – such as management information or models – being used publicly to inform Parliaments, the media and the public. In deciding whether to intervene we consider whether:

- equality of access has been preserved
- data quoted are material to public debate
- data are being used to justify important government decisions
- there is appropriate explanation of context and sources, including being clear about caveats and quality concerns
- figures form part of a coherent narrative across different sources of information

5.6.5 OSR Policy for intervention

Transparency and assessability is central to the decision to intervene, with intervention if:

1. official statistics are shared before publication
2. the advice of professional statisticians is ignored

How do in and out groups contribute or get pushed towards misinformation and if this happens really how much of a threat is it

How can we educate users in critical thinking to be able to sift and find information in the bottomless pit that is the internet"

5.7 Visuals

Misinformation is far from new, see Figures 17, 18, 19 and 20.

5.8 A Bayesian approach to information and misinformation

A rather grand perspective on information and misinformation might use ideas on biological information and information theory, in a rather loose way.

As humans, or animals, we have often no inherent information about the state of the world. To find out what is like we need to make observations, gather information, and use this to learn about the world.

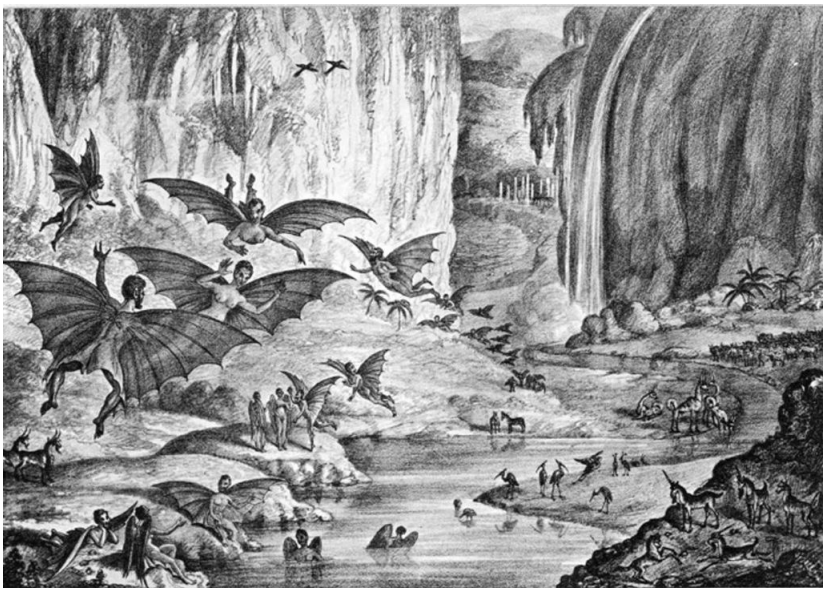

Figure 17: Great moon hoax (early disinformation example)

Figure 18: The end is nigh (Tintin, shooting star)

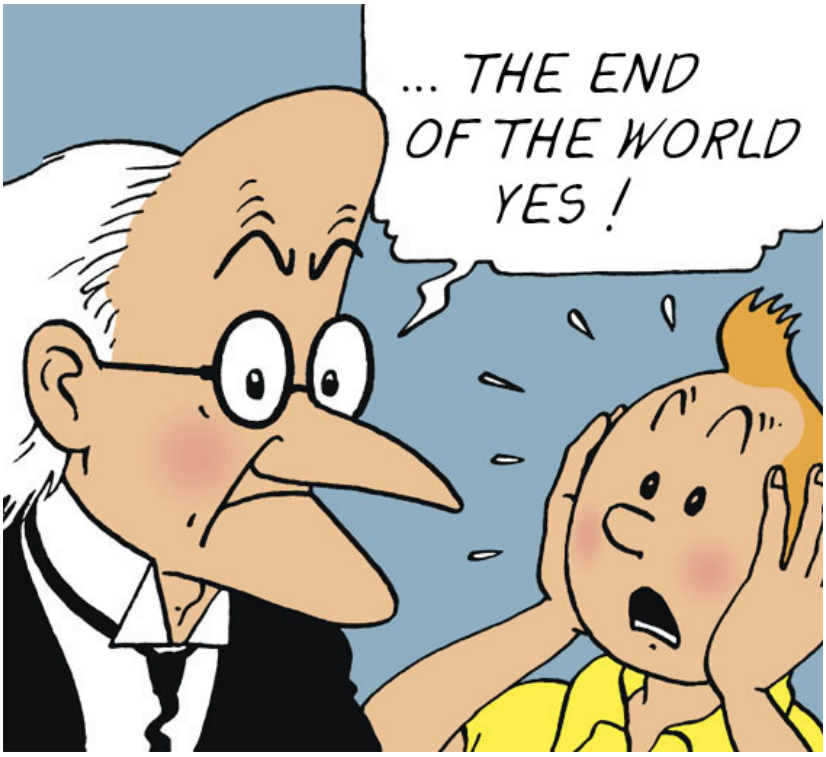

Figure 19: you can't have enough Tintin

Figure 20: Operation Infektion (KGB disinformation campaign

A way to formalise this process is through learning by means of Bayesian updating. The basic idea is that we start with a prior view of what the world is like. As we gather information we adjust our view of the world in accordance with the observations we make. Initially, our world view would have been very uncertain. For instance, if I need to fish for food, I need to know when is the best time to fish. Without ever having been to the river, I could guess that it makes no difference whether I fish at dusk, dawn or noon. But after a number of fishing trips I could update that view, as I tended to catch more fish at dawn and dusk, and less at noon.

The fishing trips are a way to explore, and personally gather information about the world. (This is a very loose description of Bayesian updating and can be used to mathematically describe the amount of information.)

Information, and learning, need not only come from personal information, it is possible that I gain information from others. If, through some form of communication, I can get other's views or observations, I can use such social information to update my world view and learn about the world.

Social information differs from personal information in that I have assurance that personal information is based on a direct observation of the world I want to learn about. With social information this is not necessarily the case: I do not really know where that information is coming from. Firstly, social information will be processed by whoever collected the information in the first place. Social information can be affected by the prior views of the person who transmitted the information and can be filtered in the process of passing on. Secondly, it is possible that the information that is passed was incorrect, possibly intentionally so. For instance, a fellow fisherman might emphasize the merits of midday fishing to protect his own catch. For either, the usefulness of social information can be affected and one should take care in using it. (there is a link to trust here)

But how do we judge or how do we quantify the usefulness of information? There is no signal in the information itself that tells us the value. The only way to tell whether the information is good or bad is by telling if it increases decreases my knowledge of the state of the world. If I know less what true state of the world is after I have used the information that I have received, that information was not helpful

This allows for a definition of the value of information, and thereby, misinformation: if I know the state of the world better after receiving the information, the value of the information is how much more I know. If the information had a positive value it is helpful, if I know less what the state of the world is the information was not helpful, and could thereby be seen as misinformation. Misinformation could thus be defined as information that leads me away from

the truth. But herein lies a problem. As an individual, I do not know what the exact state of the world is, the truth if you like, and therefore I cannot judge the value of information on this basis as the value is measured by using a touchstone which I do not have access to.

5.9 Generating policies to combat misinformation

- Firstly, avoid giving misinformation or making inadvertently misleading statements, use good practice informing not influencing attitudes. Present as fair a representation of the facts as possible and include caveats.
- There is a place for regulation and intervention at govtal or platforms, in case of social media, but any policy or enforceable regulation needs to find a balance between limiting misinformation while not infringing on other rights, such as freedom of speech and expression.

  We looked at policies of govt, social media platforms, EU
- Example, the EU has definition of misinformation, disinformation and malinformation and in some states, laws that prohibit these. But the four international special mandates on freedom of expression have stated that laws containing prohibitions on dissemination of 'false news', which are 'vague and ambiguous', are 'incompatible' with international standards on freedom of expression, and 'should be abolished'
- In terms of the remit and powers of the OSR they can act on misinformation if official statistics or data used in a document or statement are presented in such a way that they are likely to mislead the public or undermine the integrity of official statistics. However, this limits misinformation to cases where there is intent (misleading) and where the way information is used is demonstrably untrue. It needs to be verifiable that the information is not correct. This covers part, but not all misinformation. Misinformation, for instance, can be based on accurate individual facts that are misrepresented.
- There is a need for education on critical thinking. To allow the general public to exercise critical thinking. Data should be provided and be open and transparent, as should methodologies to enable repeat analysis.

Clare Wardle has developed a typology with an accompanying matrix See Figure 21, Links to Twitter thread and accompanying article.

which links the types of misinformation that are spreading and the corresponding motivations for spreading each type:

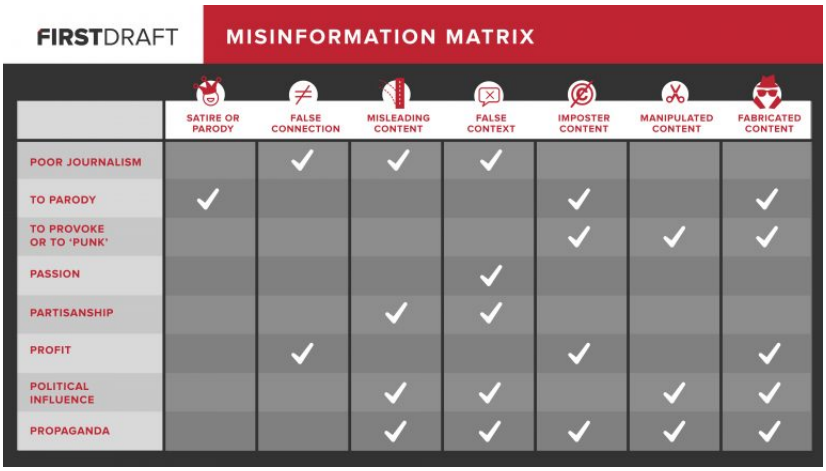

Figure 21

1. Satire or Parody: No intention to cause harm but has potential to fool
2. False Connection: when headlines, visuals or captions don't support the content
3. Misleading Content: misleading use of information to frame an issue or individual
4. False Context: when genuine content is shared with false contextual information
5. Imposter Content: when genuine sources are impersonated
6. Manipulated Content: when genuine information or imagery is manipulated to deceive
7. Fabricated Content: new content that is predominately false, designed to deceive & do harm

5.10 Bayesian model comparison

A concept that could be useful. Instead of black/white answer it produces a likelihood ratio. This is a first message, that perhaps we should not be aiming to distinguish information into two categories but to use a graduated scale.

An example is work to decide if the bones found under a carpark in Leicester were Richard III or not. The result of incorporating various strands of evidence was that the likelihood ratio was 6.7 million in favour of being Richard III. That seems to be considered as beyond reasonable doubt, though I don't know if law courts have a quantification (unlike the IPCC which has a conversion table between various phrases and probabilities). Furthermore, at least the English court of appeal has forbidden use of Bayes theorem except in connection with DNA

evidence, which I consider a terribly backward step, analogous to the Catholic church condemning Galileo. How can it be right to forbid thinking logically with probabilities? Especially when the court's decision are formulated in terms of probabilities (civil courts use the balance of probabilities, meaning 50:50).

5.11 Graduated scale for legitimacy

Adopt a probabilistic view and compute a probability p in [0,1] that the statement is true, or if preferred the odds ratio p/(1-p) [Warning: betting shops quote the odds against, (1-p)/p] or its logarithm (to whichever base you like). In civil courts the decision is in favour of the position with p>1/2 (balance of probabilities). In criminal courts conviction requires guilt beyond reasonable doubt, e.g. p>99.9%, though I don't think they ever specify a threshold. To compute the probability is not straightforward, unless a mathematically specified problem. In general, one needs to start from a prior probability (which could be 1/2, but can allow a range of options and see how it affects the outcome). Then compute the posterior probability by multiplying it by conditional probabilities, but independence assumptions come in here.

A similar approach could be applied to assessing the legitimacy of statements the OSR is asked to address.

6 Conclusions

Over the study group, potential solutions were developed and these were presented on the final day. The outcomes are summarised in the following.

- Group 1: The Trustworthy Communication group focused on addressing three main areas:
  - Definitions of trustworthiness
  - Scoring the trustworthiness of visualisations
  - Measuring the impact of verbal posts or visualisations (e.g. on Twitter) in terms of likes, shares etc
- Group 2: The Communicating Mathematics main output was a “beginner’s guide” for communicating mathematics to different audiences, including teachers, students, parents, journalists and policymakers.
- Group 3: The Misinformation group identified the following opportunities for the OSR:
  - In communicating ‘misleading’ claims, transparency, quality and value of data and methodology must be central, equipping the public with the information to critically assess claims and counterclaims.
  - By anticipating ‘hot topics’, we can anticipate how information may be used to mislead, and logical fallacies that may be employed.
  - A dashboard can provide general information on key terminology and common fallacies to equip the public.
  - Promoting statistical literacy should be at all levels, from education to responding to specific claims.

Next Steps: Following the study group, a **podcast interview** with the Communicating Mathematics challenge presenter, Tom Whipple, was conducted at the Isaac Newton Institute.

A **blog post** on ’Assessability: drafting a footnote to Onora O’Neill’ was written by Tom King of the Misinformation subgroup.

The Newton Gateway are developing follow-on event on **Communicating Mathematics for the Public** that will be held at the Isaac Newton Institute on 24th and 25th January 2023.

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