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Science Communication as a Collective Intelligence Endeavour: A Manifesto and Examples for Implementation

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Abstract

Effective science communication is challenging when scientific messages are informed by a continually updating evidence base and must often compete against misinformation. We argue for the need for a new programme of science communication as collective intelligence—a collaborative approach, supported by technology. This would have four key advantages over the typical model where scientists communicate as individuals: scientific messages would be informed by (1) a wider base of aggregated knowledge, (2) contributions from a diverse scientific community, (3) participatory input from stakeholders, and (4) better responsiveness to ongoing changes in the state of knowledge.

Keywords: science communication, collective intelligence, epistemic diversity, knowledge aggregation, participatory input, knowledge updating

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Many of the pressing challenges that societies face today, from climate change to global pandemics, require decisions informed by the best available scientific evidence. Ideally, citizens should have access to good quality scientific knowledge that they can trust. However, citizens may have difficulties accessing scientific information and grasping the technical terms used. Some of the difficulty can be mitigated by a better style of science communication, for example, using clearer and jargon-free language (Hanel & Mehler, 2019; Martínez & Mammola, 2021), more intuitive presentation formats (Pighin et al., 2011; Sirota & Juanchich, 2019; Sirota, Juanchich, & Bonnefon, 2018), effective graphics (Harold, Lorenzoni, Shipley, & Coventry, 2016), and narratives that resonate with people (Freling, Yang, Saini, Itani, & Abualsamh, 2020; Zebregs, Putte, Graaf, Lammers, & Neijens, 2015). Similarly, there is a case for supporting people's competencies to critically engage with information (Brodsky et al., 2021; Hertwig & Grüne-Yanoff, 2017; Herzog & Hertwig, 2019; Pennycook et al., 2021; Wineburg & McGrew, 2017). While these aspects are important, it is also essential to consider the content of these messages: what is the best evidence and who is involved in generating it. Scientific knowledge is continually updating, and new evidence now emerges rapidly, with gaps, uncertainties, and ambiguities in the data and its interpretation. A new programme of science communication is needed that can address these complexities and derive clear messages that (a) reflect the best available evidence and (b) are delivered in a way that maintains public trust.

Currently, individual scientists are incentivised to rapidly disseminate their findings—often at the expense of quality control (Higginson & Munafò, 2016). This can harm the reliability of scientific messages as well as public trust in them. Further, scientific messages compete in a contested and complex online landscape that favours partisanship over reasoned debate (Lorenz-Spreen, Lewandowsky, Sunstein, & Hertwig, 2020). Especially where evidence conflicts with political or commercial interests (e.g., tobacco, oil and gas, anti-vaccination, libertarian interests; Bragman & Kotch, 2021; Lewandowsky, 2021a, 2021b; Oreskes & Conway, 2010; Starbird, Arif, & Wilson, 2019), organised efforts to misinform, sow public confusion, or advance conspiracy theories have distorted public discourse (Dixon & Clarke, 2012; Koehler, 2016), threatened evidence-based policy making (Posetti & Bontcheva, 2020; Vériter, Bjola, & Koops, 2020), and personally targeted individual prominent scientists (Korecki & Owermohle, 2021; Lewandowsky, Mann, Brown, & Friedman, 2016; Mann, 2015). In this commentary, we argue that to combat the challenges of today's information landscape, science communication must go beyond "one-person reporting" and harness the collective knowledge and expertise of many scientists worldwide to provide high quality information and engage with stakeholders. In short, we propose to approach science communication as a *collective intelligence* process.

In its broadest form, "collective intelligence" can be seen as a collaborative approach to problem-solving, typically supported by technological tools, which allows for real-time co-ordination and mobilisation of knowledge that is distributed among many individuals (NESTA, 2018; Suran, Pattanaik, & Draheim, 2021). To some extent, the scientific process already embeds collective intelligence, as scientific knowledge is informed by reasoned argument between scientists, generating better outputs through peer evaluation and debate (Mercier, 2016). Here, we focus on harnessing the most advantageous characteristics of existing collective intelligence systems that would benefit science communication (Table 1). We explain why and how these characteristics could be an effective way to address specific obstacles present in the traditional, "one-person reporting" model of science communication.

Table 1. Features of collective intelligence and how these could be effectively operationalised in science communication.

Features of collective intelligence	**How it could be implemented**	**How it benefits science communication**	**Existing examples**	**Potential challenges**
Aggregates data and evidence	Infrastructure to enable many scientists to co-ordinate contributions on a research area to an organised repository.	Minimises heterogeneity and puts contradictory evidence into a wider context of evidence accumulation. Showcasing strength of evidence makes it more resistant to contrarian attack. Shifts discourse towards looking at aggregated evidence instead of proving effects.	Epistemonikos, Psychological Science Accelerator, ALL-IN protocol, ASReview	Set-up costs such as developing agreed protocols, inclusion criteria, and checks for evidence quality.
Aggregates expert judgements and discourse	Leverage tools and frameworks for collective debate and consensus-building to showcase scientific discourse and collect expert judgements.	Accumulating expert judgements increases likelihood of correct interpretation of evidence, meaning more reliable messages. Communicating accumulated scientific judgement with frameworks for its interpretation gives a more accurate picture of the level of agreement among experts and avoids presenting false balance.	Metafact; SciBeh Manifesto for Science Communication as Collective Intelligence; IPCC guidance note for consistent treatment of uncertainties	Tools to showcase collective judgements are not yet optimised for presenting scientific debate and will need refinement and adaptation. It will be challenging to aggregate expert discourse, which typically uses technical language, in a way that allows non-experts to follow.

Features of collective intelligence	How it could be implemented	How it benefits science communication	Existing examples	Potential challenges
Highlights consensus-building	Infrastructure for transparent deliberation, critique, and debate among large groups of experts to refine ideas and develop consensus statements.	Consensus statements are highly effective at counteracting denialism and shifting public attitudes in favour of evidence-based policy action.	RepliCATS, Method for Debunking Handbook 2020, TRICE, Indie_SAGE	Although many independent projects have emerged to support independent consensus-building, each remains relatively small scale. Tools to support larger-scale consensus-building are still in development. More ideas and testing of methods are needed, including ways to ensure consensus comes from a representative sampling of experts.
Increases diversity of contributions	Collective intelligence systems should prioritise epistemic diversity. Evidence-based dissent should be welcomed, with discourse mediation to focus debate on ideas rather than individuals. Frameworks can formalise how divergent perspectives should contribute in evidence syntheses. Experts can be approached systematically and independently of their prior opinions to contribute to a scientific collective.	Epistemic diversity improves scrutiny of ideas and encourages scientists to challenge their own cognitive biases. Diverse representation, especially from groups and regions typically underrepresented in science, builds trust in scientific institutions by guarding against the reinforcement of imbalanced power structures and marginalisation of groups within the scientific research community.	IPBES conceptual framework; Method for Debunking Handbook 2020	Lack of platforms for scientific discourse that support diversity without rancour. Gatekeeping needs to be balanced against preventing marginalisation—inclusive frameworks are not a failsafe for this.

Features of collective intelligence	How it could be implemented	How it benefits science communication	Existing examples	Potential challenges
Allows participatory involvement	Interfaces to allow stakeholder and public input and involvement in shaping research questions. Transparency around the scientific process helps make participation accessible to citizens.	Builds trust. Generates interest and stake in research. Increases understanding of the scientific process.	Smart Citizen; ZOE Health Study; Social listening (passive participation)	Research needs to be more accessible to encourage citizen participation. Better tools are needed to help the public understand and evaluate published research and avoid misleading argumentation.
Allows responsiveness and real-time updating	Leverage AI tools for emerging evidence identification and more quickly connect with relevant experts to evaluate research in their field. Collectives of experts can contribute as a community to updating the existing state of knowledge in real time by regularly feeding updates into these AI-supported systems.	Scientific knowledge is rapidly changing, so responsiveness will allow science communication to maintain ongoing review and evaluation and present the best available evidence at any given time point.	PubPeer, PREreview, living systematic reviews, Rapid Reviews COVID-19, Vaccine Communication Handbook and Wiki, SciBeh knowledge base	Sustaining contributions from experts over long periods can be exhausting for scientists and researchers who are already overloaded. The structure of the academic system may need to change to recognise, incentivise and thus sustain wider participation in longer-term collective intelligence efforts.

Aggregating distributed knowledge

Collective intelligence can help science communication by aggregating knowledge that is distributed among individual scientists (Suran et al., 2021). First, aggregating data and evidence can build a more complete picture of the current state of scientific inquiry, leading to more confidence in the reliability of a scientific proposition. As examples, distributed networks of laboratories can aggregate samples for an experimental protocol (Coles, Hamlin, Sullivan, Parker, & Altschul, 2022), spreading the time and labour costs of data collection and evidence syntheses (Sutherland & Wordley, 2018). Monitoring and aggregating evidence can also increasingly be done in real time with new Artificial Intelligence (AI) tools, for example, using machine learning to screen databases for relevant evidence (Rada et al., 2020).

Second, aggregating independent expert judgements can mitigate bias in evidence interpretation and enhance accurate assessment (Boland, 1989). Further, communicating judgements that fairly represent those of a collective avoids the false balance that may be presented if an audience only hears from a few, unrepresentative experts (Dixon & Clarke, 2012; Goodin & Spiekermann, 2015; Rietdijk & Archer, 2021). Showing the distribution of judgements can highlight when there is a consensus or, when judgements differ, it can illustrate the uncertainties involved in interpreting the available evidence (e.g., metafact, which displays aggregated answers to scientific questions) and experts' level of confidence in the state of knowledge (e.g., Mastrandrea et al., 2011). Critically, technologically-supported aggregation methods allow experts to add their judgements independently, reducing the risk of biases that can be introduced through group processes (Turner & Pratkanis, 1998).

Third, aggregating expert discourse, i.e., discussion of the evidence, can showcase how reasoned argument between scientists informs scientific knowledge. This can be as critical as the evidence itself, especially in crisis situations where action must be taken as evidence emerges. New digital tools for judgement aggregation in the civic participation sphere provide comprehensive packages for debating, proposing and voting on initiatives and data (e.g., Pol.is, PSi, Loomio, Consul, Decidim). These could be leveraged for communicating scientific discourse.

There are of course costs to setting up aggregation systems. To aggregate data and evidence, protocols must be developed and shared with participating researchers. Evidence quality must also be assessed to avoid undermining the accumulated knowledge base with the inclusion of unreliable data (Royal Society, 2018). When aggregating judgements and discourse, the expertise of those who are contributing needs to be verified and contributors should be representative of their collective field of research, to avoid those with vested interests gaming the power of scientific consensus (Cook, van der Linden, Maibach, & Lewandowsky, 2018).

Despite the costs, aggregation is highly beneficial. Communicating in terms of the "collective accumulated evidence" shifts the message towards what the best available evidence indicates. This can help resist arguments that science has not "proved" an effect (Oreskes & Conway, 2010). It is also harder for those interested in discrediting science to carry out ad hominem attacks on collective evidence from a group of scientists (Mann, 2015). Furthermore, accumulated evidence can make a scientific consensus more visible—which is important because well-communicated scientific consensus has influenced decision-making, shifted the public's attitudes and strengthened calls for policy action across various domains (e.g., climate change: Budescu and Chen 2014; van der Linden, Leiserowitz, and Maibach 2019; COVID-19: Kerr and van der Linden 2022; vaccinations: Bartoš, Bauer, Cahlíková, and Chytilová 2022; Linden, Clarke, and Maibach 2015), even for partisan individuals or those who tend to be predisposed towards rejecting scientific evidence (Lewandowsky, Gignac, & Vaughan, 2012). In areas where consensus has yet to form, aggregation can advance science by exposing areas in which further evidence is needed (Minas & Jorm, 2010).

Involving a more diverse group of individuals

To optimise the quality of aggregated evidence and a scientific consensus, collective intelligence should increase the diversity of contributions. First, diversity in ideas (e.g., epistemic diversity) tends to invite greater scrutiny, increasing the robustness of scientific inquiry (Pesonen, 2022). Involving more diverse perspectives may help scientists challenge cognitive biases when seeking or interpreting evidence. Second, diversity in representation can boost the reach and effectiveness of science communication, especially when it comes to producing messages that the public trusts. Historically, a lack of diversity in science and research has perpetuated inequalities and contributed to the marginalisation of voices from groups such as women, minority groups, and citizens of countries in the Global South (Almeida, 2015; Clark & Horton, 2019; Mertkan, Arsan, Cavlan, & Aliusta, 2017). This can undermine trust in science, especially among communities that experienced discrimination in the past (Razai, Chaudhry, Doerholt, Bauld, & Majeed, 2021; Woolf et al., 2021).

Diversity needs to be deliberately engineered because biases can easily be overlooked when values and norms are embedded into contemporary society. It is necessary to review processes such as consensus-building, information gatekeeping, and sensemaking, and establish transparent frameworks to incorporate diversity in these processes (Almeida, 2015; Díaz, Demissew, Joly, Lonsdale, & Larigauderie, 2015; Thapar-Björkert & Farahani, 2019). For example, frameworks for inclusion can specify how experts will be invited or selected to contribute (e.g., by issuing invitations to all identified experts in the domain, regardless of their opinions on an issue; Lewandowsky & Oberauer, 2020). These processes can now be accelerated with technological support (Chater et al., 2021). Although frameworks do not guarantee diversity, they make the lack of diverse representation more noticeable. A transparent framework for inclusion that discloses who the experts are and why they were chosen can also help verify expertise and avoid a "manufactured" collective scientific position from non-experts (e.g., Cook et al., 2018).

Designing for diversity in the scientific collective also requires constructive spaces for deliberation, critique, and debate—discourse that is essential to knowledge-building—which support diverse participation. These spaces should be built around critiquing ideas rather than individuals, with recognised codes of conduct for respectful engagement (e.g., Aurora & Gardiner, 2019). They should encourage scholars with opposing perspectives to collaborate rather than compete (e.g. "Adversarial Collaboration"). Although there is as yet no existing platform that promotes such behaviour in online academic discourse, some researchers are considering how older tools that predate the Internet, such as the Delphi Method (a structured interaction that alternates independent expert opinion elicitation with aggregation and discussion; Dalkey & Helmer, 1963) could be harnessed as a model for shaping scientific discourse among diverse experts. Tools to scale up such processes (e.g., the repliCATS project; Pearson et al., 2021) could in the near future provide online infrastructure to visualise and convey the inputs to and outcomes of the consensus.

Increasing public participation

By definition, collective intelligence is participatory, leveraging the involvement of many individuals to produce its outputs. Thus far, we have discussed the participatory input of experts in generating scientific knowledge that underpins science messages. However, science communication should also be informed by the people it will impact (Priest, 2018). Participatory input from citizens can help shape research to address the needs of those affected by it (Bruin & Bostrom, 2013; Ziegler et al., 2022). It can also generate interest and understanding from the public in how the research is conducted and evaluated (Bonney, Phillips, Ballard, & Enck, 2015; Cottrell et al., 2014), thereby building trust in scientific messages (Bedessem, Gawrońska-Novak, & Lis, 2021; Tan et al., 2022). Increasingly, technological interfaces allow the public to participate in many ways. Participation can be active, for example acting as "citizen scientists" (Silvertown, 2009) or a mass monitoring system (e.g., Zoe Health Study; Birkin, Vasileiou, & Stagg, 2021). The public can also passively inform scientists through their collective online discourse: "social listening" has enabled science communicators to tackle misinformation outbreaks by targeting information provision to the public's needs (Purnat et al., 2021; World Health Organization, 2021).

The accessibility of scientific findings is a precondition to harvest some of the benefits of public participation, such as a more knowledgeable citizenry. Accessibility can mean making research available; here, researchers are increasingly doing so through "pre-prints", that is, draft-level papers submitted to a publicly accessible server. In theory, this gives the public early sight of findings, but pre-prints can be confused for scientific fact (Wingen, Berkessel, & Englich, 2019) or weaponised to support a certain narrative (Bajak & Howeve, 2020). Hence they should only be considered as emerging evidence in an aggregated system, and this needs to be clearly indicated on the pre-print platforms and papers. Accessibility also means making research comprehensible. Openly published articles (pre-prints or otherwise) often remain inaccessible to the public because of their technical language and general level of complexity, limiting informed discussion of these to scientists and small parts of the public (e.g., science journalists, think-tanks, and policymakers). Here, increasing accessibility could involve writing plain language summaries to papers (Stoll, Kerwer, Lieb, & Chasiotis, 2022). It could involve supporting citizens' skills to engage with information and identify good quality evidence, such as teaching how to check what other evidence aligns with what they have just read (Brodsky et al., 2021; Wineburg & McGrew, 2017), or warning people about misleading arguments and how to spot them (Roozenbeek, van der Linden, Goldberg, Rathje, & Lewandowsky, 2022). Scientific publications could even be augmented with technological tools that indicate how findings correspond to the broader literature or how samples should be structured for this kind of research. Accessibility could also be enhanced with collective projects to communicate the state of the evidence in comprehensible language (e.g., the COVID-19 Vaccine Communication Handbook Lewandowsky et al., 2021). Ultimately, scientists have a duty to make research available and comprehensible to the public that provides them with funding and academic freedom (Greenwood & Riordan, 2001).

Responsiveness to changes

It can be difficult to identify relevant evidence and judge its quality at a given point in time when it can emerge rapidly, especially during a crisis situation where scientists may accelerate research production and dissemination (Else, 2020; Fraser et al., 2021; Lipworth, Gentgall, Kerridge, & Stewart, 2020). CI can leverage technology to enable real-time information monitoring, thereby enhancing the responsiveness of science communication to updates and changes. Traditional evidence syntheses are lengthy processes that often exclude the most recent studies that were not published by the time the research was conducted. In contrast, AI can enable a dynamic evidence synthesis (Community, 2019; van de Schoot et al., 2021), with some promising examples already emerging across different domains (e.g., COVID-19: Elliott et al. 2021; ecology: Christie et al. 2022). In such systems, after having established the criteria for subsequent studies to be included, researchers can regularly monitor new publications and update their synthesis in real time (Elliott et al., 2021).

Collective intelligence could also increase the responsiveness of evaluating new information. Emerging scientific papers typically undergo independent critique, or “peer review”, but this process is notoriously slow (Björk & Solomon, 2013). During the COVID-19 pandemic, researchers collectively responded by accelerating some peer review processes (Horbach, 2020) and, more commonly, openly sharing early-stage research as pre-prints. Not all rapid publication was helpful to the pandemic response (Bagdasarian, Cross, & Fisher, 2020), but some did provide valuable rapid updates to inform decision-making (Fraser et al., 2021). Identifying and accelerating the review of better quality pre-prints (Carneiro et al., 2020) could thus improve the responsiveness of science in times of crisis. A collective intelligence system could help organise and support scientific evaluation of pre-prints (and indeed published papers, which would also benefit from post-publication review; Brainerd & You, 2018), for example by identifying potential reviewers through network analysis (Price & Flach, 2017; Rodriguez & Bollen, 2008) or detecting information manipulation and erroneous statistical analyses (DeVoss, 2017; Henman, 2020; Valera & Gomez-Rodriguez, 2018).

However, AI cannot fully replace the human contributions needed for quality assurance. AI-supported tools to facilitate quicker pre-print or post-publication review by the scientific collective exist (e.g., PREreview: Johansson and Saderi 2020, RR:C19, PubPeer: Townsend 2014), but sustaining motivation to contribute collectively to this work over the longer term is difficult. This may in part be due to a lack of incentives. For example, while academics cite lack of time as a main reason for not reviewing more (Tite & Schroter, 2007), the time needed to review a manuscript, which is typically a few hours (Lewandowsky & Oberauer, 2020), is far less than the time needed to produce a new piece of research (typically months). Despite the critical contribution of peer review to the scientific process, it is not incentivised in the publication structure, nor by most employers. The same goes for maintaining contributions to consensus-building and communicating consensus. The recent COVID-19 crisis provided a glimpse of how a motivated scientific collective could produce, evaluate, and communicate research in a highly responsive fashion. However, this effort has been hard to sustain two years later. Harnessing the ability of collective intelligence in responding to crises and fast-paced research thus needs an overall structural change within the scientific community to better reward collective knowledge processes over individual efforts.

Implementing collective intelligence in science communication: An example

This commentary is itself a product of our experience harnessing collective intelligence processes to create a “Manifesto for Science Communication as Collective Intelligence”. We used group discussions and interactive online discourse via the tool pol.is to gather insights from attendees at an open virtual workshop on the topic. We then invited everyone to craft the manifesto, either as co-ordinating lead authors (“CLAs”, $n =$

6) or contributing authors ($n = 18$). CLAs collectively voted on how to organise the points raised at the workshop. Each CLA then led a group of authors to draft a section of the manifesto. The CLAs condensed this draft into its key propositions and, using pol.is, all authors voted on which propositions from the draft were critical for the manifesto. Propositions with >60% of votes were organised into the final Manifesto, which presented eight necessary features for science communication as collective intelligence. Altogether, we engaged a diverse group of researchers, captured and aggregated their judgements and discourse in an iterative fashion, and generated a consensus for communication. The full process is shared online as part of the Manifesto.

Conclusion

In this commentary, we highlighted the impetus for science communication to move away from a model where scientists disseminate individual findings and adopt a collective communication programme that (a) develops messages from a wider base of aggregated evidence, judgements, and discourse, (b) is informed by a diverse community, (c) involves participation from stakeholders, and (d) is responsive to ongoing changes in the state of knowledge. We have provided examples (see Table 1) that concretise how this new programme would leverage collective processes, supported by participatory technology, in pursuit of a more collaborative form of science communication. While no single example (including our own experience) has managed to harness all the advantages we describe in this commentary, they provide a glimpse of how collective processes are already enhancing the way in which scientists gather data, reach consensus, and communicate it. We hope that in the near future, more tools and examples will emerge to support a programme of science communication as collective intelligence.

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Competing interests

The authors declare no competing interests.

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