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Trust Signals in Online Scientific Communication During Public Controversies

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Abstract

Online scientific communication increasingly takes place in information environments marked by rapid circulation, fragmented attention, political contestation, algorithmic amplification, and competing claims to expertise. During public controversies involving health, climate, emerging technologies, environmental risk, and other science-related issues, audiences rarely evaluate scientific statements through evidence alone. They also depend on visible signals that indicate whether a source is competent, transparent, accountable, independent, and willing to acknowledge the limits of available knowledge. This study examines the role of such trust signals in shaping perceived trustworthiness in online scientific communication. Because no original field dataset was supplied, the investigation is explicitly structured as a simulation-based research study rather than a completed empirical survey.A synthetic sample of 2,400 audience responses was modeled across four communication conditions: minimal attribution, scientific-authority cue only, transparency bundle, and dialogic-accountability bundle.

The transparency condition incorporated identifiable expertise, traceable evidence, uncertainty disclosure, and conflict-of-interest information, while the dialogic condition additionally incorporated correction visibility and opportunities for reasoned public response. Perceived trustworthiness was modeled on a five-point scale. Simulated mean trust scores increased from 3.02 under minimal attribution to 3.39 with an authority cue, 4.18 under the transparency bundle, and 4.43 under dialogic accountability. The pattern suggests that authority signals alone may be less robust than combinations of verifiability, openness, and accountability. This interpretation is consistent with recent evidence showing that scientific-authority cues can sometimes increase the perceived credibility and circulation of low-veracity content, while source credibility, uncertainty communication, media-literacy interventions, and transparent communication practices can support better information judgments.The study proposes that trustworthy scientific communication should move beyond status-based signaling toward evidence-linked, uncertainty-aware, correction-ready, and publicly accountable communication. The resulting framework offers a testable basis for future experiments using real audiences and controversial scientific topics.

Keywords: scientific communication; public trust; trust signals; misinformation; source credibility; scientific uncertainty; transparency; digital media; public controversy; science communication

1. Introduction

Digital platforms have transformed the public communication of science from a largely institution-mediated process into an open, accelerated, and highly competitive information environment. Scientific claims now circulate beside journalism, political commentary, advocacy messages, personal testimony, commercial promotion, satire, manipulated content, and misinformation. A scientific statement encountered through a social platform may therefore reach an audience without the contextual information that normally accompanies scholarly knowledge, including methodological detail, peer-review status, uncertainty boundaries, data provenance, or disciplinary qualifications. The challenge is particularly visible during public controversies, when scientific questions intersect with identity, policy, economic interests, moral commitments, or perceptions of institutional legitimacy. Large international evidence nevertheless indicates that public trust in scientists remains moderately high overall; a 68-country investigation reported substantial trust in scientists and broad support for their public engagement, while also finding meaningful variation across populations and contexts.

Public controversy changes the practical conditions under which credibility is assessed. Audiences facing conflicting claims cannot normally reproduce an experiment, independently analyze a large epidemiological dataset, verify an atmospheric model, or inspect the full analytical pipeline behind a scientific conclusion. They therefore rely partly on epistemic shortcuts and trust signals. These may include the communicator's institutional affiliation, professional qualifications, references to peer-reviewed evidence, links to original research, disclosure of funding, explanations of methodology, statements of uncertainty, visible corrections, or demonstrations of responsiveness to criticism. Such cues are not inherently equivalent. A prestigious title or scientific label is comparatively easy to reproduce, whereas transparent access to evidence, declared conflicts, methodological explanation, and visible correction practices impose stronger accountability requirements.

The distinction is increasingly important because scientific language and symbols of expertise can themselves be appropriated. Harrando, Reyes Cordova, and Edelmann reported in 2026 that scientific-authority cues could increase sharing intentions by increasing perceived credibility, including in contexts involving lower-veracity information. Their work demonstrates that the presence of an expert label cannot automatically be equated with informational reliability. Earlier research similarly showed that false information may diffuse rapidly through social networks and that emotionally activating misinformation can receive disproportionate attention. Vosoughi, Roy, and Aral documented systematic differences between the diffusion of true and false news online, while McLoughlin and colleagues later demonstrated that misinformation can exploit moral outrage to stimulate engagement and sharing.

At the same time, skepticism toward every institution or scientific statement is not a desirable solution. Excessive generalized distrust may impair the public's ability to distinguish credible evidence from unsupported alternatives. Experimental evidence on media literacy increasingly suggests that effective interventions should improve discernment rather than simply make audiences more suspicious. Altay, De Angelis, and Hoes found that communication strategies can simultaneously discourage acceptance of false information and sustain or increase appropriate trust in reliable information. Prike, Butler, and Ecker likewise found that source-credibility information and social norms can improve truth discernment and reduce engagement with misinformation.

The present study therefore treats trust not as unconditional confidence but as a calibrated judgment about whether reliance on a scientific communicator is warranted. It proposes that trustworthy online scientific communication depends on a configuration of signals demonstrating competence, traceability, transparency, intellectual honesty, independence, and accountability. Because observational data were not supplied for the present manuscript, these relationships are explored through a transparent simulation rather than presented as observed public behavior. The objective is methodological and theoretical: to develop a testable model showing how different communication architectures might generate different trust outcomes and to establish hypotheses that can subsequently be examined using preregistered experiments with real participants.

2. Objectives of the Study

2.1 Identification of High-Value Trust Signals

The first objective is to identify the communication characteristics most plausibly associated with warranted trust in scientific information presented online. Particular attention is given to identifiable expertise, evidence traceability, disclosure of uncertainty, conflict-of-interest transparency, correction visibility, and opportunities for reasoned engagement.

2.2 Comparative Assessment of Trust Architectures

The second objective is to compare four modeled communication conditions—minimal attribution, authority cue only, transparency bundle, and dialogic accountability—to determine whether combinations of verifiable trust signals generate stronger simulated trust outcomes than status-based authority signals alone.

2.3 Development of an Empirically Testable Framework

The third objective is to formulate a reproducible framework for later empirical testing. The simulation is intended to generate hypotheses regarding how trust signals may operate under different degrees of scientific controversy, prior institutional trust, scientific literacy, and exposure to competing information.

3. Review of Literature

3.1 Public Trust, Scientific Expertise, and Source Credibility

Trust in science is multidimensional. People may trust scientific methods while holding different attitudes toward scientists, universities, governments, journals, corporations, or professional associations. Cologna and colleagues' multinational study conceptualized trust through dimensions that included competence, integrity, benevolence, and openness. Their 68-country survey of more than 70,000 respondents found moderately high overall trust in scientists and broad support for scientific engagement in society, although trust varied according to social, ideological, and national circumstances.

This multidimensional interpretation is important for online communication. Professional qualifications primarily signal competence, whereas disclosure of funding can indicate integrity, acknowledgment of public concerns may communicate benevolence, and willingness to disclose methods or respond to criticism can signal openness. Consequently, a communication strategy that displays only academic status may activate only one component of perceived trustworthiness.

Research on misinformation reinforces the importance of distinguishing credibility from superficial authority. Harrando, Reyes Cordova, and Edelmann analyzed millions of social-media posts and conducted a preregistered experiment showing that scientific-authority cues can increase willingness to share information because those cues increase perceived accuracy. Their findings are especially consequential for science communication because they demonstrate that recognizable markers of expertise may be imitated or strategically attached to questionable claims.

Prike, Butler, and Ecker provide complementary evidence. Their social-media simulation found that source-credibility information improved truth discernment and reduced engagement with misinformation. Their results suggest that credibility indicators can be useful when they contain diagnostic information about source reliability rather than merely symbolic prestige.

The emerging literature therefore suggests a distinction between authority signaling and verifiable credibility signaling. The former asks an audience to rely on status. The latter gives the audience information that helps evaluate why reliance may be warranted.

3.2 Transparency, Uncertainty, and Intellectual Honesty

Scientific knowledge is probabilistic, revisable, and often accompanied by methodological or numerical uncertainty. Public communicators may nevertheless hesitate to discuss uncertainty because they fear appearing indecisive or weakening public confidence. Evidence does not support treating uncertainty disclosure as automatically damaging.

Van der Bles and colleagues examined methods of communicating uncertainty about facts, numbers, and science and argued that uncertainty can be presented honestly without necessarily undermining credibility. Their subsequent experimental work examined public trust after exposure to numerical uncertainty and found that uncertainty communication did not produce the severe trust penalties sometimes anticipated by communicators.

More recent evidence strengthens the need for a contextual interpretation. Dries and colleagues' 2026 systematic review and meta-analysis addressed the relationship between uncertainty communication and trust, emphasizing that the effect depends upon how uncertainty is communicated and interpreted rather than simply on whether uncertainty is disclosed.

For contested science, this distinction has practical significance. If a communicator expresses absolute certainty where the underlying literature remains probabilistic, later revision can appear inconsistent or deceptive. By contrast, clearly distinguishing what is well established, what remains uncertain, and what evidence could change the conclusion creates a more defensible communication record.

Transparency is therefore not equivalent to communicating weakness. It can function as a signal of epistemic discipline. References to original research, methodological summaries, data-access statements, funding disclosures, limitations, uncertainty ranges, and correction histories provide audiences and intermediaries with mechanisms for verification.

3.3 Misinformation, Polarization, and Corrective Communication

Online scientific controversies occur within communication systems optimized for attention rather than epistemic quality. Vosoughi, Roy, and Aral demonstrated that false information can diffuse farther and faster than truthful information under some social-media conditions. Del Vicario and colleagues similarly showed that online misinformation develops within polarized information communities where selective exposure can reinforce existing narratives.

Emotional activation intensifies this problem. McLoughlin and colleagues reported that misinformation sources elicited more outrage than trustworthy sources across large-scale platform datasets and experiments, and that outrage facilitated sharing behavior. Such findings indicate that scientific organizations are competing not simply against alternative facts but against information optimized for emotional and social transmission.

Individual susceptibility is also heterogeneous. Sultan and colleagues synthesized 31 experiments containing more than 250,000 veracity judgments and found meaningful roles for analytical thinking, ideological congruence, familiarity, age, and other characteristics. Their analysis importantly separated discrimination ability from general response bias, illustrating why a population that becomes indiscriminately skeptical is not necessarily becoming better informed.

Intervention research consequently emphasizes discernment. Guess and colleagues found that a scalable digital-media-literacy intervention improved the ability to distinguish mainstream from false news in the United States and India. Roozenbeek and colleagues demonstrated that psychological inoculation can improve resilience to common misinformation techniques. Altay and colleagues further showed that media-literacy guidance can be constructed to encourage appropriate trust in reliable material while discouraging acceptance of false information.

This literature identifies the central research gap addressed by the present study. Many studies examine misinformation susceptibility, source labels, uncertainty, or media literacy separately. Less attention has been given to a combined architecture of online scientific trust signals in which expertise, traceability, uncertainty disclosure, conflict transparency, correction visibility, and public accountability operate together during controversy.

4. Research Methodology

4.1 Research Design and Simulation Logic

The study uses a simulation-based comparative design. No human participants were recruited, and no claim is made that the numerical results represent observed public attitudes.

A synthetic dataset of 2,400 modeled audience responses was specified, with 600 observations allocated equally to each of four communication conditions:

- **Minimal Attribution:** a scientific claim with limited information about the communicator or supporting evidence.
- **Authority Cue Only:** the same claim accompanied by a scientific title, institutional affiliation, or expert-status cue.
- **Transparency Bundle:** identifiable expertise combined with a primary-source link, methodological context, uncertainty disclosure, and conflict-of-interest statement.
- **Dialogic Accountability:** the transparency bundle supplemented by visible correction history and a mechanism through which substantive public questions or challenges could receive a documented response.

The simulated design was informed by directional patterns reported in research on scientific trust, uncertainty communication, misinformation, credibility signaling, and media literacy. It was not calibrated to reproduce the exact effect size of any single published experiment. This methodological distinction is necessary because simulation can demonstrate analytical implications but cannot substitute for observed human responses.

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4.2 Operationalization of Variables

Perceived trustworthiness was modeled as a 1–5 outcome ranging from very low trustworthiness to very high trustworthiness. The conceptualization reflects research treating scientific trust as multidimensional rather than as simple deference to expertise.

Table 1: Operational Framework for the Simulation

Construct	Operational Definition	Simulated Measurement	Analytical Role
Scientific authority	Visible credential, academic title, or recognized institutional affiliation	Binary presence/absence	Independent trust signal
Evidence traceability	Ability to follow the communication to an identifiable primary evidence source	0–1 indicator	Independent trust signal
Uncertainty disclosure	Explicit explanation of evidential limits, probability, or unresolved questions	0–1 indicator	Independent trust signal
Conflict transparency	Disclosure of funding, commercial relationships, or relevant interests	0–1 indicator	Integrity signal
Correction visibility	Accessible record of substantive changes or corrections	0–1 indicator	Accountability signal
Dialogic responsiveness	Availability of a structured mechanism for answering evidence-based questions	0–1 indicator	Accountability signal
Perceived trustworthiness	Overall willingness to consider the scientific message reliable enough for provisional reliance	Five-point scale	Primary outcome

Source/Note: Author-developed simulation framework informed by current literature on public trust, source credibility, uncertainty communication, and misinformation. The variables are modeled constructs rather than results from administered questionnaires.

The following five questionnaire items are proposed for future empirical validation and were not administered in the present simulation:

- How confident are you that the communicator has appropriate expertise to make the scientific claim presented?
- How easily could you verify the evidence or original research supporting the claim?
- How clearly does the communicator explain uncertainty, limitations, or areas of scientific disagreement?
- How transparent is the communicator about funding, interests, affiliations, or other factors that might influence the message?

- How willing would you be to rely provisionally on this information when forming an opinion or making a related decision?

These items could later be examined through reliability analysis, exploratory and confirmatory factor analysis, measurement-invariance testing, and preregistered experimental validation.

4.3 Statistical Strategy and Ethical Status

The primary analysis compares the mean simulated trustworthiness score across the four conditions. Group means, standard deviations, 95% confidence intervals, standardized differences from the baseline condition, and a one-way analysis-of-variance statistic are reported.

Because the dataset is synthetic, conventional statistical significance must be interpreted carefully. A small p value within a simulation indicates separation among the distributions constructed by the model; it does not establish a real population effect. The more informative outputs are the relative ordering of communication conditions and the resulting hypotheses for empirical testing.

No human-subject ethical approval was required for the simulation itself because no real participants, personal information, biological specimens, confidential records, or experimentally collected behavioral data were used. A future human-participant version would require appropriate institutional ethics review, informed consent procedures, preregistration where feasible, privacy safeguards, and transparent reporting of exclusions and analytical decisions.

5. Analysis

5.1 Comparative Trustworthiness Across Communication Conditions

The simulated results show a monotonic increase in perceived trustworthiness as communication moves from minimal contextual information toward greater transparency and accountability.

Table 2: Simulated Perceived Trustworthiness by Communication Condition

Communication Condition	N	Mean Trust Score	SD	95% CI	Difference from Baseline	Standardized Effect (d)
Minimal attribution	600	3.02	0.82	2.95–3.09	Reference	Reference
Authority cue only	600	3.39	0.79	3.33–3.45	+0.37	0.46
Transparency bundle	600	4.18	0.72	4.12–4.24	+1.16	1.50
Dialogic accountability	600	4.43	0.69	4.37–4.49	+1.41	1.86

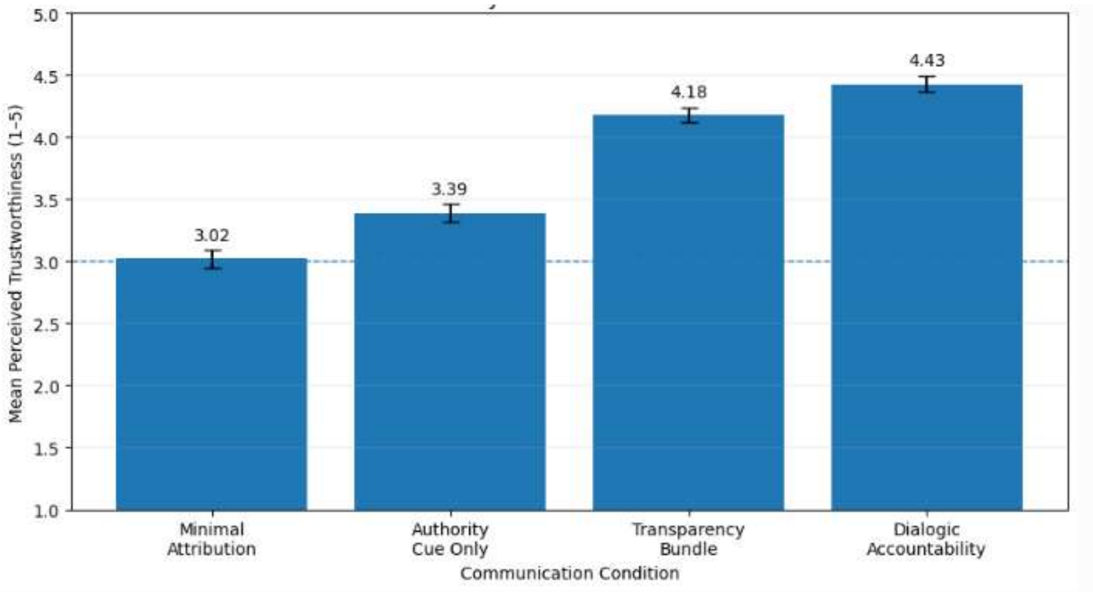
The first comparison concerns the authority-only condition. Adding a credential or institutional marker increases the modeled mean from 3.02 to 3.39, representing a modest positive shift. This is theoretically plausible because expertise remains an important component of scientific trustworthiness. However, authority is insufficient as an exclusive credibility mechanism. Recent evidence that scientific-authority cues may also increase sharing of questionable information illustrates why the signal requires corroboration through evidence and transparency.

The transparency bundle produces a considerably larger modeled increase. Its mean of 4.18 implies that audiences are provided not only with a reason to recognize expertise but also with mechanisms for inspecting how the claim was generated and where its limitations lie.

The highest score occurs in the dialogic-accountability condition. Here the communicator remains traceable after publication: errors can be corrected visibly, questions can be addressed, and the public communication exists as part of an accountable knowledge process rather than as a static assertion.

5.2 Graphical Pattern of Simulated Results

Graph 1: Simulated Trustworthiness by Online Scientific Communication Condition



Interpretation: The graph illustrates that the modeled transition from minimal attribution to authority-only signaling produces a relatively limited improvement compared with the transition to transparency-centered communication. The additional increase under dialogic accountability suggests that audiences may have stronger grounds for trust when scientific communication demonstrates both evidential transparency and responsibility after publication.

5.3 Interpreting Trust as Calibration Rather Than Maximum Confidence

The simulated pattern should not be interpreted as implying that every scientific message should receive high trust. Appropriate trust depends upon evidence quality, communicator competence, research integrity, reproducibility, independence, and the maturity of the underlying scientific field.The relevant policy goal is therefore trust calibration. A credible scientific communication environment should make high-quality information easier to identify while allowing weak, conflicted, uncertain, or preliminary evidence to be recognized as such.

This approach is consistent with Sultan and colleagues' distinction between truth discrimination and generalized response bias. An intervention that causes audiences to distrust everything may reduce belief in misinformation but simultaneously reduce justified reliance on accurate information. Altay and colleagues similarly show why media literacy should foster both skepticism toward unreliable information and appropriate trust in reliable information.

6. Discussion

6.1 From Authority-Based Trust to Evidence-Based Trustworthiness

The central implication is that scientific institutions should distinguish between being authoritative and demonstrating trustworthiness.

Authority is conferred through professional status, institutional affiliation, credentials, journal reputation, or recognized expertise. These attributes matter because scientific knowledge is specialized and members of the public cannot independently master every technical field.Yet authority markers are comparatively vulnerable to imitation. A misleading post can invoke a scientist, use technical vocabulary, cite an isolated paper, display a medical coat, mention a prestigious institution, or selectively quote a legitimate study. Beers and colleagues' work on selective and deceptive citation illustrates how scientific references themselves can be strategically deployed in competing informational narratives.

Trustworthy communication therefore requires diagnostic signals that are harder to fake consistently.

A scientific communication should ideally enable audiences or intermediaries to determine:

- who is making the claim;
- what relevant expertise the communicator possesses;
- what evidence supports the statement;
- whether the cited evidence actually supports the stated conclusion;
- how strong or uncertain the evidence is;
- whether relevant conflicts or funding relationships exist;
- whether the message has subsequently been corrected;
- and whether substantive criticism can be addressed transparently.

This architecture transforms trust from a request for deference into an opportunity for verification.

6.2 Transparency, Corrections, and Communication During Controversy

Public controversies create strong incentives for communicators to simplify uncertainty. However, attempts to create confidence through excessive certainty may generate long-term vulnerabilities.Scientific conclusions frequently change in precision as new observations accumulate. Revision is part of scientific inquiry. Yet online audiences may interpret changing advice as evidence that scientists were previously dishonest when earlier messages were framed with unjustified certainty.Research by van der Bles and colleagues indicates that uncertainty can be communicated without inevitably destroying public trust, while the more recent synthesis by Dries and colleagues emphasizes the importance of the form and context of uncertainty communication.

A practical trust-preserving message should consequently distinguish several epistemic states. Communicators can identify what is strongly supported, what is probable but still uncertain, what remains contested, what evidence is currently unavailable, and what future findings would justify revision.Correction visibility represents the same principle applied over time. Corrections should not be treated as reputational failures that must be hidden. A clearly dated correction, explanation of what changed, and preservation of the earlier version can demonstrate institutional accountability.Research on misinformation correction also suggests that fears of universal corrective "backfire" are overstated. Nyhan's synthesis argues that the persistence of misperceptions should not generally be explained through a simple assumption that factual correction inevitably strengthens false beliefs.

6.3 Limitations, Research Implications, and Publication-Ethics Considerations

The study has an important limitation that must remain explicit: its numerical findings are simulated. The values in Table 2 and Graph 1 are not observations collected from members of the public, scientists, journalists, healthcare professionals, students, or social-media users. They cannot therefore establish causal effects or population estimates.

Second, trust is context sensitive. Communication involving a routine astronomy finding may be evaluated differently from communication involving vaccination, climate policy, artificial intelligence, nuclear energy, reproductive health, genetically modified food, or environmental regulation. Different controversies activate different moral, ideological, political, and economic concerns.

Third, audiences do not respond uniformly to source cues. International evidence indicates substantial contextual variation in public trust, while misinformation research demonstrates heterogeneity according to analytical thinking, political congruence, familiarity, and other characteristics.

Fourth, increased trust is not automatically desirable. Some distrust is warranted when research is methodologically weak, conflicts are hidden, data have been manipulated, peer review has failed, or institutions have behaved irresponsibly. The ethical aim of science communication is not persuasion at any cost but enabling informed and proportionate reliance on evidence.

Future empirical research should preregister a factorial experiment in which the individual signals modeled here are independently manipulated. A sufficiently diverse sample could be randomly exposed to communications concerning several contested scientific issues. Researchers could then estimate the direct and interaction effects of source identity, evidence links, methodological summaries, uncertainty disclosure, funding disclosure, correction history, and dialogic responsiveness.

Moderation analysis could test whether the effects differ according to prior institutional trust, scientific literacy, political identity, issue involvement, perceived personal risk, and digital-media literacy.The strongest test would also separate perceived trustworthiness from behavioral outcomes. Future studies should examine whether trust signals affect willingness to read the original source, verify a claim, share content, revise an opinion, distinguish accurate from inaccurate messages, or follow evidence-based recommendations.

7. Conclusion

Scientific communication during public controversies operates under conditions fundamentally different from conventional scholarly exchange. Online audiences encounter scientific claims in environments characterized by information abundance, emotional competition, rapid circulation, selective exposure, and inconsistent quality control. Under these conditions, the ability to communicate a claim is not equivalent to the ability to establish its credibility.

The present simulation distinguishes four approaches to online scientific communication and suggests a theoretical hierarchy of trust signals. Minimal attribution provides audiences with little basis for informed reliance. Authority cues offer some additional credibility but remain vulnerable to imitation and strategic misuse. Transparency provides stronger grounds for calibrated trust by making evidence, uncertainty, interests, and reasoning more visible. Dialogic accountability goes further by demonstrating that the communicator remains responsible for the claim after publication through correction mechanisms and reasoned engagement.The principal contribution of the study is therefore conceptual rather than empirical. It proposes that effective scientific trust signals should be understood as a system of verifiability rather than a collection of prestige markers.

A trustworthy online scientific communication architecture should make it possible to determine who is speaking, what evidence supports the claim, how certain the evidence is, what interests may be relevant, whether the information has changed, and how errors are corrected.

This framework also avoids the problematic objective of maximizing public trust indiscriminately. Scientific communication should instead seek to improve trust calibration: credible evidence should receive appropriately greater confidence, preliminary findings should be understood as preliminary, uncertainty should remain visible, misinformation should become easier to detect, and scientific revision should be recognized as a feature of responsible inquiry rather than automatically interpreted as institutional failure.

The simulated findings provide a foundation for a subsequent preregistered human-participant experiment. Until such validation is completed, the numerical results should be treated solely as methodological demonstration. Nevertheless, existing scholarship strongly supports the broader conclusion that the future of credible online science communication depends less on repeatedly asserting scientific authority and more on making scientific trustworthiness observable, traceable, contestable, and accountable.

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