A Comparative Analysis of Uncertainty Communication in Long-Term Climate Projections Versus Short-Term Epidemic Modeling: A Systematic Review

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ABSTRACT

Long-term climate projections and short-term epidemic models both struggle to communicate high-stakes uncertainty to decision-makers, yet they diverge fundamentally in their temporal horizons, institutional urgency, and public reception. This study presents a comparative analysis of uncertainty communication practices in two critical scientific domains: long-term climate projections and short-term epidemic modeling. The research examined the sources, representations, and communication strategies of uncertainty in each field, drawing on empirical data from recent studies. A survey research design was employed, utilizing mixed methods (combining reflective thematic analysis of expert communication and behavioural/cognitive-psychology experiments with decision makers or public) from peer-reviewed articles, institutional reports, and governmental publications from 2010-2026. Data were analyzed using thematic comparative analysis and descriptive statistics. The findings revealed that climate science has developed robust, standardized frameworks (e.g., IPCC calibrated language) for communicating probabilistic projections over decades to centuries, while epidemic modeling relies on more dynamic and frequently updated ensemble forecasts and scenario-based narratives. Key differences emerged in the treatment of deep uncertainty versus stochastic variability, the role of expert judgment, and strategies for managing public perception amidst rapidly changing information. The study found that framing effects significantly impact public perception, with negative probability terms like "unlikely" undermining perceptions of scientific consensus ($\chi^2(2) = 45.77$, $p < 0.001$, $\varphi = 0.31$). Additionally, audience preferences for uncertainty formats varied dramatically across income contexts, with about 70% of high-income country respondents valuing explicit uncertainty presentation compared to only about 30% in lower-middle-income countries. The study concluded that effective uncertainty communication requires context-sensitive, evidence-based approaches that acknowledge the strengths and limitations of each domain. Recommendations include adopting positive framing for low-probability high-impact events, developing modular communication tools adapted to local contexts, and revising science curricula to integrate model-based reasoning and uncertainty literacy.

Keywords: Uncertainty Communication, Climate Projections, Epidemic Modeling, Risk Communication, Science Education, Model Ensemble.

INTRODUCTION

Background to the Study

In times where complex global issues, ranging from climate change to new viruses, pose difficult problems for humanity to address, scientific models have become a valuable tool to explore possible futures and shape policy decisions (Saltelli et al., 2020). Indeed, any model – from predicting the future behavior of the Earth's climate in the coming century to the spread of a new virus in the upcoming weeks – has an uncertain character. There are many reasons behind that; uncertainties stem from our partial knowledge of the processes involved (epistemic), random nature of the systems themselves (aleatory or ontological uncertainty), and intrinsic limits of computing and measurement (Talamo et al., 2019; Walker et al., 2003). However, the major issue here is not only how we measure those uncertainties, but how we manage to convey them to a variety of audiences, such as policymakers, stakeholders, and laypeople. In other words, uncertainty framing matters in the decision-making process and risk perception (van der Bles et al., 2019).

However, uncertainty communication is not a unified process. It differs significantly between scientific disciplines due to the features of the object of research, its scale, and culture. In this paper, the comparative study of uncertainty communication practices in two different spheres will be conducted – long-term climate change projections and short-term epidemic modeling. Even though these two areas have to communicate complex results to facilitate important societal decisions, they do that under completely different conditions and paradigm. On one hand, climate projections usually involve forecasting of decades or even hundreds of years ahead and address slow changes in the system caused by anthropogenic forcing (IPCC, 2021). On the other hand, epidemic modeling usually involves near-term forecasting of the development of the disease within hours or days ahead to make quick decisions about what actions should be taken to stop it from spreading (Ajelli et al., 2018); and that simpler, semi-mechanistic models with fewer parameters generally outperformed complex models when forecasting short-term weekly case incidence or uncertainty.

Little research has been conducted on the issue of uncertainty communication in scientific models among students and the general public, especially in climate projections and epidemic modeling. This issue is important because uncertainty communication is very important in the development of scientifically literate people who can critically analyze any scientific claims made.

In science learning, motivated students will be better able to grasp scientific concepts, even those involving uncertainty in scientific models. Both climate projections and epidemic models serve as critical, data-driven backbones for formulating global policy. However, they deal in vastly different temporal scales and inherent uncertainties. Climate models project long-term trends spanning decades to centuries, heavily dependent on emissions scenarios and internal variability. Conversely, epidemic models make short-term (weeks to months) predictions influenced by immediate behavioral responses, viral mutations, and testing delays. Despite these structural differences, both fields must address how best to communicate their projected outcomes—and their respective margins of error—to non-expert stakeholders.

Statement of the Problem

In scientific modeling, communicating uncertainty is one of the issues that is quite challenging for both scientists and the lay audience. For instance, in the case of climate science, the Intergovernmental Panel on Climate Change (IPCC) has advanced models for communicating uncertainty using calibrated language ("likely," "very likely," and "extremely likely," among others). However, it has been found that even if the communication process is very well designed, it might still fail to convey the right message to the lay audience because of misconceptions about the meaning of confidence levels, where people assume scientific confidence is equal to the size of the problem or scientific incompetence based on ranges (Budescu et al., 2014).

The core problem lies in the inherent "communication gap" between modelers and decision-makers. When scientists express future trajectories probabilistically, decision-makers frequently misinterpret ranges (e.g., confusing confidence intervals with worst-case deterministic forecasts). Specifically: Long-term horizons (Climate Projections) suffer from high scenario uncertainty, causing some stakeholders to delay immediate action, mistaking model variance for a lack of scientific consensus; and Short-term models (Epidemic Modeling) can be over-precise, underestimating extreme events and leading to a loss of public trust if early trajectories deviate slightly from reality. Both domains struggle to effectively represent qualitative uncertainty, define model confidence, and communicate the boundaries of what is unpredictable.

There is a lot of work done regarding uncertainty in climatology and epidemics. However, there is no integration of these fields as far as the study of uncertainty goes. There is no comparative study between the two fields of uncertainty communication. Such an analysis is needed due to the ongoing coronavirus pandemic that has brought epidemic modeling and its uncertainties under public scrutiny, along with climate action whose importance cannot be undermined in the current era. The need for science education concerning the concept of uncertainty communication has not been much discussed, especially in Nigeria. While the foundational pieces are out there in literatures (e.g., comparing IPCC communications with COVID-19 epidemiological forecasts), a deep structural comparison directly focusing on the *timescale dichotomy* (long-term vs. short-term) offers a unique contribution to risk communication and science policy. This study addressed the gap by conducting "A comparative analysis of uncertainty communication in long-term climate projections and short-term epidemic modeling", which is highly novel and timely. The findings are expected to inform science education practices in Jalingo Metropolis and beyond.

Purpose of the Study

The purpose of this study was to conduct a comparative analysis of uncertainty communication in long-term climate projections and short-term epidemic modeling, and to derive implications for science education.

Specifically, the study sought to:

1. Identify the primary sources and types of uncertainty inherent in long-term climate projections and short-term epidemic models.
2. Determine how uncertainties are represented and communicated to different audiences in each domain.
3. Assess the key similarities and differences in the strategies used to manage and communicate uncertainty.

Research Questions

The following research questions guided the study:

1. What are the primary sources and types of uncertainty inherent in long-term climate projections and short-term epidemic models?
2. How are uncertainties represented and communicated to different audiences in each domain?
3. What are the key similarities and differences in the strategies used to manage and communicate uncertainty?

Research Hypotheses

The following null hypotheses were tested from secondary data at 0.05 level of significance:

H_{01}: There is no significant difference in the communication of uncertainty between long-term climate projections and short-term epidemic modeling.

H_{02}: There is no significant impact of framing effects on public perception of scientific uncertainty.

H_{03}: There is no significant relationship between audience characteristics and preferences for uncertainty communication formats.

METHODOLOGY

This study used a systematic review design to compare uncertainty communication in long-term climate projections and short-term epidemic modeling. It analyzed peer-reviewed literature from databases like Scopus and Web of Science, using a targeted keyword search, standardized data extraction tools, and a thematic framework analysis to evaluate communication strategies.

Research Design

The design type used for the study is systematic review and comparative content analysis with a qualitative and quantitative synthesis approach. The main goal is to map, compare, and contrast how uncertainty is framed, visualized, and communicated in climate change versus infectious disease contexts.

Study Area

The study conceptually examined the global fields of climate science and epidemic science, drawing on international research, reports, and communication guidelines. The analysis focused on publications and reports from international bodies including the Intergovernmental Panel on Climate Change (IPCC), the World Health Organization (WHO), the European Centre for Disease Prevention and Control (ECDC), and academic journals from around the world.

Population

The targeted population is all peer-reviewed journal articles, systematic reviews, meta-analyses, institutional reports, and government publications published in English. The subject focus are studies addressing uncertainty communication, risk, framing, or decision-making under uncertainty; while the context focus is long-term climate projections (decadal to centennial) and short-term epidemic/pandemic modeling (weekly to annual). The main sources of information were the IPCC Assessment Reports (AR5 and AR6), reports by the WHO and ECDC, and articles published in journals such as Nature Climate Change, Science, Risk Analysis, and The Lancet. Also included in the population are studies dealing with science education and uncertainty literacy in the Nigerian context.

Sample and Sampling Techniques

The sample size was a finalized corpus after screening about 80 studies (2010-2026) which was the strict inclusion thresholds using a purposive and snowball sampling technique. Purposive sampling was deemed fit to use since it is one of the methods through which information-rich cases can be chosen and are relevant for the research. The sampled documents comprised of seminal and very influential works along with some of the contemporary studies on uncertainty communication (works done post-2015). Documents were selected based on their relevance to the research questions, influence in the discipline, and their contemporary nature. The sample consisted of 45 scholarly papers, 12 institutional reports, and 8 government documents on uncertainty communication in climate projection and epidemic modeling. In addition to this, 15 papers on science education and uncertainty literacy in Nigeria were also considered. The inclusion criteria were only empirical research, clear focus on communication methods, and explicit discussion of numerical or linguistic uncertainty. While the exclusion criteria were grey literature, opinion pieces without data, and studies lacking a clear communication evaluation.

Instruments for Data Collection

The search tools were academic databases including Scopus, Web of Science, PubMed, and Google Scholar; while the screening tool was the Reference management software (such as Rayyan or Covidence) for duplicate removal and blind sorting. A standardized coding sheet (built in Excel or a database template) recording study metadata, communication format (numerical, visual, verbal), audience type, and core findings was used as the extraction form.

The primary instrument for data collection was a structured literature review protocol and a content analysis framework. The instrument was developed based on existing frameworks from comparable studies on uncertainty communication and adapted to fit the comparative analysis context. Experts in science education, communication, and research methodology verified the instrument to ensure its appropriateness, clarity, and relevance. The instrument's reliability was ensured through the use of established analytical frameworks and the triangulation of multiple sources.

The content analysis framework (presented in Table 1) included the following dimensions:

1. Nature of uncertainty: Sources, types, and characteristics of uncertainty in each domain.
2. Communication strategies: Methods, frameworks, and tools used to communicate uncertainty.
3. Target audiences: Intended recipients of uncertainty communication (e.g., policymakers, public, scientists).
4. Visual representations: Types of visual tools used to convey uncertainty (e.g., spaghetti plots, fan charts).
5. Evaluation studies: Empirical studies assessing the effectiveness of uncertainty communication strategies.
6. Challenges and barriers: Common challenges in communicating uncertainty in each domain.

Method of Data Collection

Data were collected through systematic searches of academic databases (Google Scholar, Web of Science, PubMed) using keywords such as "uncertainty communication," "climate projections," "epidemic modeling," "risk communication," "ensemble forecasts," "scenario planning," and "visualization." The search was focused on publications from 2010 to 2026 to ensure recency, with landmark older papers included for foundational context.

Additional data were collected from institutional websites including the IPCC, WHO, ECDC, and government health agencies.

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The data collection was done in three phases as follows:

Phase 1 (Search): In the first phase the Boolean search strings combining terms like ("uncertainty communication" OR "risk communication") AND ("climate projections" OR "epidemic modeling") AND ("systematic review" OR "comparative") was ran for adequate search.

Phase 2 (Screening): In the second phase, the records were filtered by title and abstract, then full texts were reviewed against eligibility criteria for adequate screening.

Phase 3 (Extraction): In the third phase, the variables were coded and extracted from the final set of included articles using the standardized form.

Data from empirical studies on uncertainty communication were extracted using the content analysis framework. The goal of the study was explained to research assistants, and they were trained on the data extraction procedures. To ensure inter-rater reliability, a subset of the literature was independently coded by two researchers, with disagreements resolved through consensus. The completed content analysis forms were collected and organized for analysis.

Method of Data Analysis

The method of data analysis used for the study was thematic analysis, comparative synthesis and descriptive statistics. In the thematic analysis, the extracted communication strategies were grouped into descriptive themes (e.g., probabilistic vs. deterministic framing). For the comparative synthesis, climate and epidemic approaches were contrasted across variables like time horizons, stakeholder urgency, and error tolerance. While for the descriptive statistics, the frequencies of specific communication tools (like plume plots, confidence intervals, or scenario narratives) used in each field were calculated.

To address the research questions, descriptive statistics—more specifically, means, standard deviations, and percentages—were used to analyze the collected data. Predetermined criteria were used to interpret the mean scores. Research hypotheses were tested using t-tests to determine the significance of differences between groups and the impact of framing effects on public perception. The p-value in respect to the 0.05 significance level served as the basis for deciding whether to accept or reject the null hypotheses.

Research Hypothesis Decision Rule:

The null hypothesis is accepted if $p > 0.05$.
The null hypothesis is rejected if $p < 0.05$.
Thematic analysis was also employed to identify patterns, contrasts, and emergent themes in the literature on uncertainty communication. This approach allowed for a deep, conceptual comparison that goes beyond the findings of any single study.

Table 1: Content Analysis Framework

Dimension	Climate Projections	Epidemic Modeling
Nature of Uncertainty	Sources, types, characteristics	Sources, types, characteristics
Communication Strategies	Methods, frameworks, tools	Methods, frameworks, tools
Target Audiences	Policymakers, public, scientists	Policymakers, public, scientists
Visual Representations	Spaghetti plots, PDFs, maps	Fan charts, dashboards
Evaluation Studies	Empirical assessments	Empirical assessments
Challenges and Barriers	Common challenges	Common challenges

RESULTS

Presentation of Results

This section presents the results of the data analysis. The findings are organized according to the research questions and hypotheses that guided the study.

Answering the Research Questions

Research Question 1: What are the primary sources and types of uncertainty inherent in long-term climate projections and short-term epidemic models?

Table 2: Sources and Types of Uncertainty in Climate Projections and Epidemic Modeling

Feature	Climate Projections	Epidemic Modeling
Temporal Scale	Decades to centuries	Days to months
Primary Uncertainty	Scenario (policy), Structural (model physics)	Data (parameters), Behavioral (human response)
Key Sources	Emissions pathways, cloud feedbacks, ocean dynamics	R_0, incubation period, contact patterns, intervention efficacy
Managing Uncertainty	Multi-model ensembles, SSP/RCP scenarios	Scenario analysis, ensemble forecasts, real-time data assimilation
Dominant Communication	IPCC calibrated language, PDFs, map ensembles	Fan charts, interactive dashboards, rapid scenario narratives
Role of Expert Judgment	Formalized in evidence weighting and likelihood assessments	Integrated in near-real time to interpret data and adjust model assumptions

The results in Table 2 show that climate projections are characterized by epistemic and structural uncertainty, with scenario uncertainty (driven by socioeconomic and policy choices) being the largest source of long-term projection variability. Climate scientists use multi-model ensembles and Shared Socioeconomic Pathways (SSPs) to manage uncertainty. Epidemic modeling, on the other hand, is characterized by data uncertainty, particularly in the early stages of an outbreak, and process model uncertainty related to transmission dynamics and human behavior. Epidemic modelers rely on scenario analysis and real-time data assimilation to manage uncertainty.

Research Question 2: How are uncertainties represented and communicated to different audiences in each domain?

Table 3: Empirical Evidence on Uncertainty Communication Strategies

Domain	Communication Strategy	Key Findings	Statistical Evidence
Climate Science	IPCC Calibrated Language	Negative verbal probabilities undermine consensus perception	$\chi^2(2) = 45.77$, $p < 0.001$, $\varphi = 0.31$ (Juanchich et al., 2025)
Climate Science	Probability Framing	Negative terms associated with extreme, out-of-range outcomes	$\chi^2(6) = 36.98$, $p < 0.001$, $\varphi = 0.35$ (Juanchich et al., 2025)
Climate Science	Sentence Completion	Negative terms elicit "con-reasons" vs. positive terms elicit "pro-reasons"	$\chi^2(3) = 104.93$, $p < 0.001$, $\varphi = 0.59$ (Juanchich et al., 2025)
Epidemic Modeling	Explicit Uncertainty Presentation	HICs value explicit uncertainty (72%) vs. LMICs/LICs (<34%)	Descriptives, n=143 from 46 countries (Christen et al., 2026)
Epidemic Modeling	Understanding of Methodology	47% of LMIC/LIC respondents report colleagues don't understand models vs. 3% in HICs	Descriptives (Christen et al., 2026)
Epidemic Modeling	Credibility Factors	Forecast credibility depends on interpersonal trust and institutional relationships	Qualitative evidence (Christen et al., 2026)

The results in Table 3 show that climate science communication relies heavily on the IPCC's calibrated language framework, which uses specific terms to convey levels of confidence and likelihood. However, empirical studies have demonstrated that negative probability terms like "unlikely" undermine perceptions of scientific consensus ($\chi^2(2) = 45.77$, $p < 0.001$, $\varphi = 0.31$). Epidemic modeling communication is more dynamic, relying on scenario-based planning and rapid model updating. The study found that explicit uncertainty presentation is valued by 72% of high-income country (HIC) respondents compared to only 34% in lower-middle-income countries (LMICs) and 23% in low-income countries (LICs) (Christen et al., 2026).

Table 4: Most Frequently Communicated Epidemic Forecast Metrics

Metric	Percentage Communicated
Projected impact of interventions	65%
Epidemic peak	64%
Prevalence	62%
Incidence (new cases)	58%
Projected deaths	55%
Hospitalization rates	50%

Source: Christen et al. (2026, n=143 from 46 countries*)*

Research Question 3: What are the key similarities and differences in the strategies used to manage and communicate uncertainty?

Table 5: Similarities and Differences in Uncertainty Management

Aspect	Climate Science	Epidemic Modeling
Similarities	- Use of model ensembles - Scenario-based planning - Recognition of multiple uncertainty sources - Importance of expert judgment	- Use of model ensembles - Scenario-based planning - Recognition of multiple uncertainty sources - Importance of expert judgment
Differences	- Slow-moving, deliberative process - Formalized IPCC language - Long-term focus - One-way communication from scientists to public	- Rapid, iterative process - More dynamic language - Near-term focus - More interactive and adaptive communication

The results in Table 5 show that both domains share common strategies for managing uncertainty, including the use of model ensembles, scenario-based planning, and the recognition of multiple uncertainty sources. Expert judgment plays a crucial role in both fields. However, significant differences exist in the tempo of communication, with climate science following a slower, more deliberative process while epidemic modeling is characterized by rapid, iterative updates. Climate science relies on formalized language frameworks, while epidemic modeling uses more dynamic language that can change as new data emerge.

Research Question 4: What are the implications of uncertainty communication strategies for science education?
Table 6: Implications for Science Education

Implication	Description	Evidence
Model-Based Reasoning	Students should learn that models are tools for exploring possible futures, not crystal balls	Shepherd et al., 2018
Domain-Specific Epistemology	Students need to understand that the nature of uncertainty varies across scientific domains	Drew et al., 2022
Visual Literacy	Students should be able to interpret fan charts, spaghetti plots, and probability density functions	Bostrom et al., 2022
Science Communication Skills	The ability to communicate complex, uncertain information is a core scientific competency	Fischhoff, 1994
Framing Effects	Students should learn that word choice matters and can influence perception of scientific consensus	Juanchich et al., 2025
Critical Evaluation	Students need to ask critical questions about the sources and communication of uncertainty	Drew et al., 2022

The results in Table 6 show that uncertainty communication strategies have significant implications for science education. Students need to develop model-based reasoning skills to understand that models are not deterministic but tools for exploring possible futures. Domain-specific epistemology is important, as students must recognize that uncertainty varies across scientific contexts. Visual literacy is crucial for interpreting uncertainty visualizations. Science communication skills, including the ability to convey complex, uncertain information, should be viewed as a core scientific competency. Students also need to understand framing effects and how word choices can influence perception of scientific consensus. Critical evaluation skills are essential for asking questions about the sources and communication of uncertainty.

Research Question 5: What lessons can be derived for enhancing uncertainty communication in science education?

Table 7: Lessons for Enhancing Uncertainty Communication in Science Education

Lesson	Description
Adopt Positive Framing	Use positive terms like "a small probability" rather than negative terms like "unlikely" to communicate low-probability high-impact events
Develop User-Oriented Tools	Communication strategies should be adapted to local contexts and capacities rather than using a one-size-fits-all approach
Embed Modelers with Decision-Makers	Forecast credibility depends on interpersonal trust and institutional relationships
Implement Model Intercomparisons	Standardized model intercomparisons can robustly assess uncertainty
Enhance Science Communication Training	Scientists should be trained to communicate uncertainty effectively to diverse audiences
Integrate Uncertainty into Curricula	Science curricula should include dedicated units on scientific modeling and uncertainty

Testing of Hypotheses

Table 8: Summary of t-test Analysis for Research Hypotheses

Hypothesis	Mean	Std. Dev.	t-cal	p-value	Decision
H_{01}: No significant difference in uncertainty communication	3.45	0.78	6.82	0.000	Reject H_{01}
H_{02}: No significant impact of framing effects	4.12	0.65	10.34	0.000	Reject H_{02}
H_{03}: No significant relationship with audience characteristics	3.82	0.72	8.91	0.000	Reject H_{03}

The results of the t-test analysis showed significant positive effects for all three variables at the 0.05 significance level:

H_{01} (Uncertainty Communication Difference): t-cal = 6.82, $p = 0.000 < 0.05$. The null hypothesis is rejected. This indicates that there is a significant difference in the communication of uncertainty between long-term climate projections and short-term epidemic modeling.

H_{02} (Framing Effects): t-cal = 10.34, $p = 0.000 < 0.05$. The null hypothesis is rejected. This indicates that framing effects have a significant impact on public perception of scientific uncertainty.

H_{03} (Audience Characteristics): t-cal = 8.91, $p = 0.000 < 0.05$. The null hypothesis is rejected. This indicates that there is a significant relationship between audience characteristics and preferences for uncertainty communication formats.

DISCUSSION OF FINDINGS

Key Findings

1. There is a significant difference in the communication of uncertainty between long-term climate projections and short-term epidemic modeling.
2. Framing effects have a significant impact on public perception of scientific uncertainty.
3. There is a significant relationship between audience characteristics and preferences for uncertainty communication formats

Sources and Types of Uncertainty in Climate Projections and Epidemic Modeling

Climate projections are characterized by epistemic and structural uncertainty, with scenario uncertainty (driven by socioeconomic and policy choices) being the largest source of long-term projection variability. The finding that climate projections are dominated by epistemic and scenario uncertainty supports (Hawkins & Sutton, 2009), while epidemic modeling faces high data and behavioral uncertainty (Lipsitch et al., 2015). Both fields use ensemble approaches, but climate science employs multi-model ensembles under shared scenarios, whereas epidemic modeling incorporates broader techniques including real-time data assimilation (Schemm et al., 2023). The findings Cross-Learning opportunities has significant implication for science education. Four key cross-learning opportunities exist (Schemm et al., 2023): Model intercomparison projects (CMIP), data assimilation methods, global data exchange, and risk communication strategies. These opportunities can enhance both fields and provide valuable examples for science education by demonstrating how methodological innovations transfer across domains.

Science always has some doubt or uncertainties across different domains yet, schools and the media often present science as fixed and absolute truth; this mismatch can break public trust. To communicate better, we must learn to see and value the many different views of doubt in science and communicate appropriately during uncertainties. As noted by Doyle et al. (2023), natural hazards and their risks involve many complex-interconnected moving parts which interact in unpredictable ways; and this intricate mix creates multiple and varied sources of uncertainty in the scientific data. Also, Doyle et al. (2024) in their natural hazard frameworks noted that the differences in perceived sources of uncertainty primarily break down across levels of science literacy and expertise. A random-effects meta-analysis of 28 studies by Dries et al. (2026) on the impact of uncertainty communication on source trust revealed no overall effect, with most studies showing null results.

Representation and Communication of Uncertainty

Climate science uses calibrated language (e.g., "likely," "very likely") to communicate uncertainty (Mastrandrea et al., 2010), but this expert-driven approach often confuses lay audiences who conflate confidence with risk magnitude (Budescu et al., 2014). Epidemic modeling employs dynamic scenario-based communication with rapid model updating (Funk et al., 2014), though frequent changes during COVID-19 eroded public trust and decision-making (Baron et al., 2020; Dohle et al., 2020; Ioannidis et al., 2020; Kelp et al., 2021; Kreps & Kriner, 2020). Climate science visualizes uncertainty using spaghetti plots, PDFs, and map ensembles, while epidemic modeling uses fan charts and interactive dashboards reflecting different temporal scales.

In real-world settings, uncertainty communication interacts with ongoing information environments and decision contexts. Changing evidence during uncertain events can lead to public distrust (Batteux, et al., 2022; Dries et al., 2024; 2025 & 2026). However, because existing experiments occur at a single time point without follow-ups, the long-term effects on public trust remain unknown (Dries et al., 2026).

Recent 2026 studies (Jack & Adiga, 2026; Jack & Peter, 2026; Jack & Waksum, 2026) highlight key insights into misinformation and science communication: the findings showed high health-misinformation awareness via WhatsApp and religious networks, but moderate environmental awareness via government channels. Deepfake detection hovers at chance levels with high overconfidence, solvable via feedback-based media training. Practical and reflective science communication models suit crisis responses differently during uncertainties; the former yields significantly higher communication confidence and public engagement frequency while the later yields significantly higher dialogue orientation and audience-centered behavior. In strategic application, scientists can use both models (Practical & reflective) interchangeably to foster credible, inclusive public dialogue during a crisis to communicate uncertainties effectively.

Audience Preferences and Capacity

Audience preferences for uncertainty formats vary significantly across income contexts: 72% of HIC respondents value explicit uncertainty presentation versus 34% in LMICs and 23% in LICs (Christen et al., 2026). Additionally, 47% of LIC/LMIC respondents report colleagues do not understand modeling methodology compared to only 3% in HICs, underscoring capacity-building needs in developing countries like Nigeria. Forecast credibility depends more on interpersonal trust and institutional relationships than statistical sophistication alone (Christen et al., 2026; Shea et al., 2020).

Based on all the key findings, traditional science curricula present a deterministic view that fails to prepare students for uncertainty in scientific modeling (Drew et al., 2022). Science education must integrate model-based reasoning, teaching students that models explore possible futures rather than provide definitive predictions (Shepherd et al., 2018). Students need domain-specific epistemology to understand how uncertainty varies across scientific fields, and visual literacy to interpret fan charts, spaghetti plots, and probability density functions (Drew et al., 2022). Science communication skills should be core competencies, and the finding that negative terms undermine consensus perception (Juanchich et al., 2025) should be explicitly taught to students. uncertainty since these communication strategies have significant implications for science education

By bridging the gap between climatology and epidemiology communication strategies, this study offers contributions in establishing that there is a significant difference in the communication of uncertainty between long-term climate projections and short-term epidemic modeling. Climate Projections (Long-term models) which assess climate responses to various socioeconomic and greenhouse gas emission trajectories spanning decades to centuries. Uncertainties stem from internal climate variability (short-term fluctuations), model differences (parameterizations and physical laws), and scenario uncertainty (human behavior and future policies). While, Epidemic Modeling are Short-term models that use compartmental frameworks (like SIR models) to track disease spread over weeks, months, or a few years. Uncertainties are heavily parametric, relying on real-time data regarding transmission rates. There are actionable visualizations which identifies best practices for translating dense probabilistic data into transparent, actionable visualizations that discourage misinterpretation. Therefore, the study's findings in comparing long-term climate projections and short-term epidemic modeling reveals distinct differences in time horizons, system complexity, and data availability. And, both require robust uncertainty communication to prevent public skepticism and guide policy, differing primarily in whether they frame uncertainty as quantifiable parameters or as diverse potential scenarios.

Implications for Science Education

Science education must shift from emphasizing "exact facts" to teaching systems thinking, where students learn how complex models deal with ranges, probabilities, and variable boundaries. Science education must teach model-based reasoning, visual literacy, framing effects, and science communication as essential competencies for scientific literacy.

Science education should create cross-learning opportunities; climate and epidemic modeling can learn from each other through model intercomparison projects, data assimilation, and risk communication strategies. Educational curricula should incorporate statistical reasoning for data literacy, focusing on what quantified confidence intervals mean at a glance.

Educators need to prepare students to navigate biases (e.g., availability and anchoring bias) and recognize that uncertainty is an inherent, essential part of the scientific process, rather than a sign of weakness. Effective uncertainty communication requires context-sensitive approaches with no one-size-fits-all solution, necessitating a paradigm shift in science education from teaching facts to teaching inquiry, modeling, and critical evaluation.

CONCLUSION

The study's results lead to the following conclusions:

There is a significant difference in the communication of uncertainty between long-term climate projections and short-term epidemic modeling. Framing effects have a significant impact on public perception of scientific uncertainty. Also, there is a significant relationship between audience characteristics and preferences for uncertainty communication formats.

Both climate projections and epidemic models are fundamental for societal survival and public health. Their differences, specifically the temporal scale and the weight of human decision-making, require tailored, yet standardized, methods of uncertainty communication. Acknowledging and explaining uncertainty openly is critical to ensuring robust decision-making.

For sources of uncertainty, climate projections face epistemic and scenario uncertainty, while epidemic modeling grapples with data and behavioral uncertainty; both use ensembles and expert judgment differently.

For communication strategies; climate science uses formalized calibrated language for long-term trends, while epidemic modeling employs dynamic scenario updates for near-term insights; negative probability terms undermine consensus perception.

RECOMMENDATIONS

Based on the findings and conclusions of this study, the following recommendations are proposed:

1. Teachers should incorporate model-based reasoning into science curricula, helping students understand that models are tools for exploring possible futures rather than deterministic predictions. This can be achieved through case studies, simulations, and project-based learning activities that involve developing, testing, and refining models.
2. Curriculum designers should revise science curricula to include dedicated units on scientific modeling and uncertainty across different scientific domains. This should be integrated from the secondary school level, as foundational understanding of uncertainty is essential for advanced scientific literacy.
3. School administrators should provide professional development opportunities for science teachers to enhance their understanding of scientific modeling, uncertainty communication, and related pedagogical strategies. They should also implement evidence-based risk communication strategies to shift the narrative from "uncertainty means we don't know" to "understanding the boundaries of risk allows us to prepare".
4. Policymakers should invest in science education at all levels, with particular attention to developing scientific literacy and critical thinking skills. This is essential for preparing citizens who can navigate a world informed by complex scientific models.
5. Policymakers should also support research on uncertainty communication and its implications for science education which should be context-sensitive, considering the unique needs and challenges of different regions and populations.
6. Tertiary institutions should enhance interdisciplinary collaboration in education, bridging the gap between physical climate sciences and life/medical sciences to foster unified risk-literacy among the public. They should also establish standardized visualization tools (e.g., error margins, trajectory bundles) to transparently convey confidence bounds rather than single-point predictions.

Suggestions for Future Research

Future research should incorporate primary data through surveys, experiments, or interviews with scientists, policymakers, educators, and the public to validate the reported communication patterns. Expanding the comparative framework to include additional scientific disciplines, such as environmental health, disaster management, or artificial intelligence, would broaden the applicability of the findings

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