Navigating Climate Change Uncertainty: A Three-Study Investigation of a Short-Term Intervention on Epistemic Beliefs and Multiple Text Integration

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Dedication

To Xavier, the goodest boy, in memoriam.
Thanks for keeping me company during all those late nights writing…
this one's for you.

Abstract

Individuals hold topic-specific epistemic beliefs about the nature of knowledge and knowing within a domain. These beliefs span dimensions related to the nature of knowledge (e.g., simplicity and certainty) and the nature of knowing (e.g., sources and justification). While epistemic beliefs are generally stable, they are also amenable to change—particularly in response to targeted interventions.

This dissertation presents three experiments investigating whether a brief textual intervention can prompt epistemic change in the context of climate science, and whether such change affects how individuals comprehend and integrate multiple texts. Experiment 1 tested whether an epistemic sensitization text targeting topic-specific epistemic certainty could lead to differences in participants' beliefs. Results showed statistically significant differences in beliefs about the certainty of knowledge within climate science, suggesting that even short interventions can promote epistemic change. Experiment 2 assessed whether these changes in beliefs translated to improved multiple text comprehension and integration. No significant effects were found. Experiment 3 further explored whether multiple text integration tasks themselves could contribute to epistemic change, either alone or in conjunction with the intervention, but again yielded null results.

Together, these findings provide preliminary evidence that epistemic beliefs—particularly beliefs about the certainty of knowledge—can be influenced through brief interventions. However, the effects of such changes on downstream comprehension processes remain uncertain. This work contributes to ongoing efforts to understand how to support learners in navigating complex, uncertain topics like climate change and may inform future educational strategies aimed at fostering critical thinking in information-rich, and often misinformation-rich, environments.

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Chapter 1:
Introduction

Public understanding of science often hinges on a paradox: science is celebrated for its openness to revision, yet this very tentativeness can be mistaken for uncertainty or disagreement—even when consensus exists. This tension is especially consequential in the context of climate change, where decades of research have produced strong scientific agreement on anthropogenic climate change. While it once took a mounting body of evidence for scientists to make this claim, nearly all climate scientists now agree on its validity (Sinatra et al., 2014). And yet, the perception of uncertainty persists. This disconnect between scientific consensus and public belief raises urgent questions about how individuals interpret scientific texts, evaluate competing claims, and form beliefs about complex and evolving issues like climate change. Understanding this gap requires attention to *epistemic cognition,* or how individuals judge the certainty, complexity, source, and justification of scientific claims.

Research Context & Background

Epistemic cognition is the "thinking that people do about what and how they know" (Sandoval et al., 2016). In addition to basic cognitive processes (e.g., reading, computing) and metacognitive processes (e.g., monitoring comprehension), people engage in a distinct set of cognitive processes uniquely used in evaluating knowledge (i.e., epistemic cognition). These processes are essential for navigating an information-rich and often contradictory world.

To participate meaningfully in society as informed citizens, individuals must reflect not only on *what* they know but *how* they know it. Their beliefs about knowledge—its certainty, complexity, source, and justification—influence how they interpret new information, particularly in areas like climate science where misinformation and scientific consensus often collide. As globalization and technological advancement accelerate the flow of both credible and misleading information, research in epistemic cognition has surged over the past three decades.

Of particular interest within the topic of climate change is how epistemic beliefs—especially beliefs about the certainty of knowledge—interact with how people engage with texts. Prior research has demonstrated that short-term, topic-specific interventions can shift epistemic beliefs, and that these beliefs are associated with multiple text comprehension performance. Taken together, these findings suggest a complex

interaction between epistemic belief formation, text-based reasoning, and the potential for educational interventions to promote epistemic change.

Research Aims and Questions

Although research on epistemic cognition and text comprehension has grown substantially, less is known about how to design effective interventions that promote long-term epistemic change—especially in relation to climate science, a domain characterized by complexity and uncertainty. Existing models of multiple text comprehension describe how epistemic beliefs influence reading and integration processes, but more research is needed to address whether and how such beliefs might be modified through reading or writing tasks. This gap presents an opportunity to examine whether brief, targeted interventions can shift epistemic beliefs and, in turn, influence how individuals read, integrate, and reason across multiple, conflicting texts.

This research program investigates whether and how epistemic beliefs about the certainty of climate science can be changed, and whether such change impacts multiple text comprehension and integration—or vice versa. Specifically, the following research questions guide the three experimental studies:

1. Can a brief textual intervention about epistemic certainty in climate science lead to significant differences in people's certainty beliefs?
2. If there are significant differences resulting from the intervention, does that lead to better multiple-text comprehension and integration of climate information?
3. Conversely, can engaging in multiple-text integration tasks lead to significant differences in epistemic certainty about climate science?

Together, these questions aim to address a broader issue: What is the nature of the relationship between epistemic beliefs about climate science and the processes of multiple text comprehension and integration? This research contributes to our understanding of whether epistemic beliefs are malleable in the context of climate change, and whether such malleability supports deeper engagement with complex scientific information.

Overview of Methodology

To address these questions, this research program included three experiments that examined—both independently and in combination—the effects of (1) reading a brief epistemic intervention text and (2) engaging with multiple conflicting texts on climate

change through comprehension and integration tasks, with a focus on changes in epistemic beliefs, particularly regarding the certainty of knowledge.

The decision to separate these questions into multiple studies was due to their conceptual complexity. First, although existing models of multiple text comprehension highlight the role of epistemic beliefs in task performance, they do not explain how those beliefs can be changed. Therefore, before testing whether such a change can improve text comprehension, it was necessary to first examine whether epistemic change could be achieved through a targeted intervention.

Second, while epistemic certainty beliefs have been shown to predict comprehension performance, the tasks themselves may also influence individuals' beliefs. Thus, the contribution of the task—and the possibility of reciprocal influence—warranted investigation.

By conducting three experiments—one focused on the effect of the intervention text alone, one on the effect of the task alone, and one combining both—this program begins to unpack how brief text-based interventions and comprehension tasks can promote epistemic change related to climate change and affect how people interpret scientific texts.

The intervention text used in this study was designed to promote epistemic change by targeting readers' beliefs about the certainty of knowledge in climate science. It conveyed that while scientific certainty requires careful integration of evidence, some domains—like climate science—contain conclusions supported by a high degree of certainty.

This focus reflects current discussions in epistemic cognition literature (Kerwer & Rosman, 2018), which critique the outdated notion that epistemic development involves a linear progression from certainty to uncertainty. Instead, adaptive epistemic beliefs should reflect the nature of the domain; in scientific fields like climate change, denying certainty where it exists can be counterproductive.

As Sinatra et al. (2014) explain, "Although it is useful to understand that science is tentative and evolving and that a substantial body of mounting evidence was necessary for scientists to state that climate change has human causes, it is also beneficial to understand that nearly all climate scientists are quite certain about this claim now." Public misunderstanding of this certainty has real consequences. For example, ExxonMobil's deliberate efforts to promote doubt about climate science—highlighted in the #ExxonKnew

campaign—reveal a strategic awareness that uncertainty beliefs can undermine public understanding (Supran & Oreskes, 2017).

Ultimately, epistemically sophisticated individuals should adopt evaluativist beliefs: they recognize that while knowledge can evolve, some conclusions are well-justified by evidence. In climate science, this includes the human causes of climate change. This dissertation explores whether such evaluativist beliefs can be supported through targeted intervention and engagement with multiple texts.

Significance of the Study

This study contributes to ongoing efforts to understand how people form, revise, and apply epistemic beliefs—especially in response to complex and socially significant scientific issues like climate change. While existing models of multiple text comprehension highlight the importance of epistemic beliefs for reading and reasoning, less is known about how these beliefs can be changed, and what role educational interventions might play in that process.

By testing the effects of a short epistemic intervention and examining how readers engage with multiple texts about climate change, this research offers several contributions. Theoretically, it adds to the growing body of work on topic-specific epistemic cognition by investigating how beliefs about the certainty of knowledge may shift and influence downstream comprehension tasks. It also helps refine models of multiple text integration by considering how tasks themselves might trigger epistemic change.

Practically, this work informs the design of educational materials and interventions that promote scientifically accurate, adaptive epistemic beliefs—beliefs that are especially critical in the context of climate science, where public understanding continues to lag behind scientific consensus. If brief, targeted interventions can promote greater understanding of the nature of scientific knowledge, they may offer scalable tools for improving science education and public engagement.

Finally, this study addresses an urgent societal need. Climate change is not only a scientific issue, but also an epistemic one: the decisions individuals and policymakers make often hinge on how they evaluate the reliability, certainty, and credibility of climate science claims. Supporting epistemically sophisticated engagement with such claims is essential to promoting informed reasoning, combating misinformation, and supporting evidence-based decision-making in a rapidly changing world.

Structure

This dissertation follows the APA Style Journal Article Reporting Standards (*Publication Manual of the American Psychological Association, Seventh Edition*, 2019), which outline core reporting elements for quantitative, qualitative, and mixed methods research.

- **Chapter 1** (this chapter) introduces the research questions, rationale, and theoretical background.
- **Chapter 2** provides an in-depth review of relevant literature.
- **Chapters 3, 4, and 5** provide the method, results, and study-specific discussion for each experiment.
- **Chapter 6** presents an integrated discussion of findings, limitations, and implications.

In sum, this dissertation investigates whether and how a brief epistemic intervention and multiple text comprehension tasks can influence readers' certainty beliefs about climate science—and how these beliefs, in turn, affect their ability to integrate and reason across texts. By examining these relationships across three studies, this research contributes to our understanding of epistemic cognition, educational intervention design, and science comprehension in the context of climate change.

The following chapter provides a detailed review of the theoretical frameworks, empirical findings, and scholarly debates that inform this work, including models of epistemic cognition, multiple text integration, and science communication.

Chapter 2:
Literature Review

This chapter's primary aim is to provide an in-depth overview of the literature on climate change uncertainty, epistemic cognition, epistemic change, and multiple-text comprehension, connecting the dots between them to understand the complexity of combating climate change misinformation and subsequent inaction. The second aim is to clarify why the following set of research studies is significant and uniquely contributes to the field. The third aim is to explain the rationale for the research designs and methodologies undertaken and why they are appropriate for this research.

Climate Change Knowledge

Climate change is a *socio-scientific issue* (i.e., a controversial, real-world scientific issue that is ill-structured, open-ended, and complex (Sadler, 2004)). In fact, climate change is a quintessential socio-scientific issue because it necessitates the integration of complex scientific understanding with ethical reasoning, social values, economic considerations, and political actions to develop effective and equitable solutions to one of the most pressing challenges facing humanity (Gardiner & Hartzell-Nichols, 2012). For more than five decades, some sources of climate change information have been bad actors attempting to “discredit climate science and confuse political debate on climate change, by casting doubt on well-supported theories and providing alternative and often fallacious interpretations of observations” (Treen et al., 2020). The impacts of these campaigns are well documented (Mann, 2021). As a result, people have varying, strong beliefs and emotions associated with the topic, and itis now a controversial, complicated issue that regularly draws attention from the psychological, social, and behavioral sciences, and is frequently studied and addressed with topic-level specificity (e.g., the American Psychological Association Climate Change Task Force).

Climate change communication has been its own research topic since the 1980s when ExxonMobil instigated a major disinformation campaign (Supran et al., 2023), which tried to instill widespread skepticism about the validity of climate change research results. Ironically and tragically, these efforts were simultaneous with ExxonMobil’s own climate change research supporting rising temperatures. As documented by Supran & Oreskes (2017), ExxonMobil and others achieved a strategic development of public doubt by consistently emphasizing the uncertainties inherent in the scientific understanding of climate change. Despite ExxonMobil’s own research and internal models forecasting

warming trajectories (Supran et al., 2023), ExxonMobil's communications highlighted the supposed ambiguity in scientific conclusions about the potential enhanced greenhouse effect (e.g., Carlson, 1988). They framed the discourse around the debate, casting potential remedies as impractical, excessively costly, or simply unfeasible (Supran & Oreskes, 2017, 2020), and actively promoted doubt from the period 1989-2004 at minimum (Supran et al., 2023).

While it would be challenging to empirically determine the causality between a long history of such climate misinformation and the current prevalence of climate change denial, both climate misinformation and skepticism persist today (Gounaridis & Newell, 2024). Recent tactics by the many actors involved in fostering climate change skepticism (Dunlap & Brulle, 2020) have expanded from the proliferation of climate change skepticism to include many different tactics to impose difficulties with the adoption of behaviors that could stop climate change. These tactics are characterized as one of two overarching types of climate misinformation: epistemic (related to beliefs around climate science) and response (related to climate solutions) (Cook, 2020).

Given the duration, expansion, and breadth of strategies used in climate misinformation, many cognitive processes likely need to be understood to explain underlying mechanisms and design effective, theory-based interventions. The current set of studies focuses on one specific belief resulting from climate misinformation—epistemic uncertainty—and tests whether a targeted, theory-based intervention can create change that reduces doubt. Practically, addressing this question is important because there is a need to develop interventions that could counteract the entrenched skepticism surrounding climate science that leads to inaction. Theoretically, addressing this question is important because regardless of research outcomes, the results will contribute to the body of knowledge of existing theories on changing epistemic beliefs, including Bendixen and Rule's Process Model and conceptual change models (for more on these models, see Mechanisms of Epistemic Change below). Results from this line of research will provide insights about enduring challenges in learning and cognition. They will also illuminate the efficacy of text-based interventions to counter misinformation and foster the evidence-based reasoning that is essential for a scientifically literate society.

Epistemic Cognition

Epistemic cognition is the intricate process by which individuals reflect on the nature of knowledge and knowing. Trying to understand and mitigate future potential

attempts at fostering similar doubt, then, relies on deep understandings of both epistemic beliefs—first defined broadly, now studied granularly as research has increasingly supported domain- and topic-specific epistemic beliefs—and the narrow example of the ExxonMobil manipulation of public understanding beginning in the 1970s. Despite advancements in understanding the communicative elements that foster such skepticism and the development of frameworks detailing the interplay between epistemic cognition and knowledge acquisition, significant gaps remain. The nuances of epistemic beliefs, their malleability, and the extent to which they can be influenced under specific conditions are still not fully comprehended, let alone studied at the necessary level of specificity.

Models of Epistemic Cognition

In thinking about how best to understand doubt and uncertainty as a cognitive process, the subfield of psychology focused on "epistemic cognition" provides a theoretical framework within which research has aimed to understand the construct. *Epistemic cognition* is the "thinking that people do about what and how they know." Variations among individuals in their beliefs about the certainty of knowledge, the complexity of knowledge, the process of justification for knowledge, and the sources of knowledge are theorized to define an individual's epistemic cognition (Hofer & Pintrich, 1997). For example, an individual's epistemic cognition about the COVID-19 vaccine includes the extent to which that person believes that knowledge about the vaccine is sure and unchanging, or uncertain and evolving; the extent to which that person believes that knowledge about the vaccine is simple or complex and highly interrelated; the extent to which that person believes that knowledge is handed down by authority or acquired by reasoning (e.g., knowledge is actively constructed); and a person's understanding of how a belief about the vaccine becomes justified knowledge, ranging from personal experience and subjective opinion to through systematic inquiry. Additionally, an individual will have beliefs about knowledge within the domain of vaccines more broadly, as well as beliefs about knowledge in general, which will inform how they evaluate the information they come across relating to the COVID-19 vaccine.

In our current "post-truth" world, an increasing emphasis has been placed within education to move beyond the mere acquisition and use of information, and to focus more on such critical evaluation of information (Greene et al., 2016). This emphasis creates a need to both understand the beliefs about knowledge that contribute to an individual's ability to critically evaluate information (i.e., epistemic cognition), and create interventions

that change this process to be more adaptive (i.e., epistemic change). The following sections expound upon theory and research regarding epistemic cognition and how it develops.

Modern psychological research on epistemic cognition began with the work of William Perry (1970) who, based on interviews with male students at Harvard University, first proposed that college students' beliefs about knowledge and knowing progress along a successively adaptive continuum associated with educational experiences. While this developmental model was based on less-than-ideal research practices (e.g., using a non-representative, all-male sample from an elite university), replications with broader samples resulted in the observation of similar patterns (e.g., Kuhn et al., 2000).

Since then, research in epistemic cognition has taken different paths that can be categorized into one of three perspectives: the developmental perspective, the beliefs perspective, and the resources perspective. Developmental models of epistemic cognition have characterized a trajectory of epistemic development as consisting of a linear progression through phases, and, particularly within earlier models, tend to include beliefs about learning and ability in addition to beliefs about knowledge and knowing. Schommer (1990) was the first to propose that the developmental stages of epistemic cognition were characterized by dimensions; these dimensions included structure, stability, and source of knowledge, and ability and speed of learning. While others followed, the most popularly used model of epistemic development to date is still the one by Kuhn et al. (2000), in which individuals successively progress across four stages of *realism, absolutism, multiplism,* and *evaluativism,* in that order. Realism characterizes the views of very young children, who perceive knowledge to be a direct reflection of reality (Kuhn & Weinstock, 2002). The subsequent stage of absolutism is characterized by a belief that knowledge is certain and that an objective truth exists, while the following stage of multiplism is characterized by the belief that knowledge is inherently subjective. Finally, evaluativism, which is characterized by acknowledgement of the importance of weighing evidence and integrating contradictory knowledge claims before concluding about a given knowledge claim (Kerwer & Rosman, 2018), is considered to be an epistemic goal with many domains, including science. Evaluative beliefs are desirable not only because they reflect a weighted, careful integration of various knowledge claims, but because they have shown to positively affect other behaviors, such as academic achievement. Other developmental

psychologists have proposed similar models that reflect systematic progression through similar stages (Kitchener, 2002; Perry, 1970).

Other developmental models have uniquely differed from traditional developmental models of epistemic cognition that propose a linear progression through stages. For instance, a model posited by Chandler et al. concedes that many children start at the same stage of realism (which resembles absolutism); however, individuals can move into either of two different stages, dogmatism or skepticism; while both are characterized by seeing knowledge as human construction, dogmatists believe that knowledge comes from authority, while skeptics believe that knowledge is not possible. Individuals can then move onto rationalism (which resembles evaluativism according to Schommer). Models of epistemic cognition such as these, which propose that epistemic change is not linear, are increasingly supported by research findings such as those that have found that young students can hold relatively advanced, topic-specific epistemic beliefs (Greene & Yu, 2014) and that individuals can undergo epistemic change in ways of decreasing sophistication (Kienhues et al., 2008).

Overall, excepting some unique models such as the one proposed by Chandler et al., educational psychologists have been critical of developmental models. Criticisms include synchronous variation and development across dimensions, domain generality of beliefs, and suggestions that epistemic development doesn't occur before college years (e.g., Greene et al., 2008). In this way, Schommer's (1990) development of the first multi-dimensional model of epistemic cognition and set a path for both beliefs and resources approaches to epistemic cognition. Her work purported several dimensions of epistemic cognition, setting the groundwork "systems of beliefs" approach. This approach suggests that different epistemic positions aligned with different stages of epistemic cognition proposed by developmental psychologists may be held by an individual, that changes in beliefs can occur in different directions, and that, based on the context-specificity of the use of epistemic beliefs, the fruitfulness of holding certain epistemic beliefs may differ. Since Schommer's (1990) work, educational psychologists have proposed several "systems of beliefs" models for epistemic cognition, none more widely used than Hofer and Pintrich's (1997) *Framework for Epistemic Cognition*.

Hofer and Pintrich's (1997) Framework for Epistemic Cognition

Research efforts in modeling epistemic cognition have largely focused on defining the dimensions of beliefs that are involved in epistemic cognition and their relationships to

each other. One of the more widely used models is that conceptualized by Hofer and Pintrich (1997). Hofer and Pintrich's work, building off of Schommer's (1990), rejected the inclusion of beliefs about learning and teaching in epistemic cognition; they acknowledged that while there may be a close relationship between these beliefs and beliefs about knowledge and knowing, they are conceptually distinct constructs. According to their framework of epistemic cognition, *epistemic beliefs* include two dimensions of beliefs concerning the nature of knowledge (*simplicity of knowledge* and *certainty of knowledge*) and two dimensions of beliefs concerning the nature of knowing (*source of knowledge* and *justification for knowing*).

Each of these four dimensions is thought to reflect a continuum. Simplicity of knowledge ranges from the belief that knowledge is an accumulation of isolated facts, to the belief that knowledge consists of interrelated concepts. Certainty of knowledge ranges from the belief that knowledge is absolute and unchanging, to the belief that knowledge is tentative and evolving. Source of knowledge ranges from the idea that knowledge originates outside of one's self and resides in external authority, to the idea that knowledge is actively constructed by the person through interacting with others. Justification for knowing ranges from justifying knowledge through observation and authority, to using inquiry and evaluating and integrating different sources.

Since the conception of Hofer and Pintrich's framework, other models have recharacterized the dimensions underlying the epistemic cognition construct. Greene et al. (2008), in returning to the philosophical origins of epistemic cognition theory, rejected the inclusion of the two dimensions of beliefs concerning the nature of knowledge (simplicity and certainty beliefs), instead arguing for these to be reclassified as dimensions of ontological cognition. His model of epistemic and ontological cognitive development integrates dimensions from educational psychology with progressions from developmental psychology. He asserts that developmental progressions exist for each dimension across realism, dogmatism or skepticism, and rationalism.

These philosophically informed understandings have been further supported by Chinn et al. (2011), whose proposed philosophically grounded framework for epistemic cognition includes five parts: (a) the sources and justification of knowledge and other epistemic achievements and related epistemic stances, (b) the structure of knowledge, (c) epistemic aims and values, (d) epistemic virtues and vices, and (e) reliable and unreliable processes for achieving epistemic aims. Unlike Greene et al.'s (2008) framework, certainty

beliefs are included in Chinn et al.'s (2011) framework. They are included in the stance component of the sources and justification of knowledge and other epistemic achievements and related epistemic stances, while complexity beliefs are subsumed by the structure of knowledge.

Regardless of whether certainty beliefs are epistemic or ontological, the nature of knowledge, or epistemic stances related to sources and justification of knowledge, these models agree that certainty beliefs are an important dimension of epistemic cognition that influences individuals' information processing.

Mechanisms of Epistemic Change

Bendixen and Rule's Process Model. Bendixen and Rule's (2004) process model of epistemic change provides a theoretical mechanism for how cognitive disequilibria could cause epistemic change under certain conditions. The authors posit that when an individual feels dissonance (e.g., they feel that their views are inadequate in light of new information) and personal relevance (e.g., they are interested in the issue), the conditions allow for a mechanism of epistemic change, consisting of three components.

First, individuals must experience epistemic doubt, a cognitive dissonance, that leads to questioning one's epistemic beliefs. This may happen in response to new information that contradicts an individual's preexisting epistemic beliefs. This epistemic doubt, combined with epistemic volition or the motivation for epistemic change, can lead to a change in epistemic beliefs through resolution strategies (e.g., reflection) leading to the adoption of more adaptive epistemic cognition. including terms such as sophisticated, adaptive, availing, or effective epistemic cognition (Cartiff et al., 2021).

These three sequential components that drive belief revision according to this model—epistemic doubt, epistemic volition, and resolution strategies—do not guarantee the development of more adaptive epistemic cognition, however. Outcomes depend on how doubt is resolved: strategies may lead to sophisticated beliefs (e.g., integrating new perspectives), regression to simpler certainties, or stasis if information is dismissed as irrelevant or untrustworthy. The model underscores that progression requires both sustained motivation (volition) and effective strategies to navigate uncertainty, emphasizing epistemic change as a non-linear, complex, and effort-dependent process.

Conceptual Change

Conceptual change research has guided interventions on epistemic change within educational psychology, aligning with Bendixen and Rule's process model that suggests

that epistemic doubt is the first stage of epistemic belief revision. This is because conceptual change interventions leverage doubt in one's false beliefs before directly addressing and refuting misconceptions with a new belief for replacement.

Prior Research Based on Models of Epistemic Change

Several text-based interventions have been shown to be effective in inducing epistemic change, including the use of short texts (Flemming et al., 2020; Kienhues et al., 2008, 2011). These interventions have borrowed from conceptual change theories and Bendixen and Rule's (2004) process model for epistemic development, the former of which informed the development of the latter on proposing conditions necessary for change in epistemic beliefs.

Research on conceptual change focuses on the role of existing knowledge structures in the acquisition of new knowledge on the same concept, largely with concern for changing naïve conceptions or misconceptions to include individuals' acquisition and subsequent use of scientifically accepted knowledge. Generally, conceptual change theories focus on the discrepancy between existing beliefs, scientifically accepted knowledge to be acquired, and the mechanisms and conditions for that acquisition. Several of these models, such as the original Conceptual Change Model (CCM; Ambrosio et al., 2011) and the Cognitive Reconstruction of Knowledge Model (CRKM; Dole & Sinatra, 1998) emphasize a dissonance with an existing belief, as well as other characteristics of both individuals and the message presenting the scientifically accepted knowledge, for conceptual change to occur.

Such models prompted the proposal by Bendixen and Rule (2004) for a mechanism and conditions of change. To date, the *Process Model for Personal Epistemology Development* (Bendixen, 2002) is one of the few, if not the only, models proposing a mechanism for epistemic change. This model specifies the conditions under which individuals will undergo epistemic change. These mechanisms include epistemic doubt, epistemic volition, and resolution strategies. Epistemic doubt involves creating dissonance with one's current views (Bendixen & Rule, 2004). Epistemic volition describes the intention and commitment to make a focused effort to overcome epistemic doubt. Resolution strategies describe a reflection to resolve epistemic doubt. In explicitly stating and refuting commonly held epistemic beliefs, short text interventions for epistemic change target the mechanisms of epistemic doubt leading to epistemic change, looking to leverage what is known about conceptual change to confront readers with the inaccuracy

of their current epistemic beliefs while providing a more explanatory belief with which to replace them (Kienhues et al., 2008).

Several researchers have already tested the utility of similar texts as short-term interventions for changing epistemic beliefs. Flemming et al. (2020) tested whether refutation text could facilitate readers' epistemological understanding of abstract concepts and influence subsequent behavior across multiple settings, topics, and populations. By providing a text that directly refuted and addressed the misconception of how the tentativeness of scientific findings relates to low scientific credibility of a journalistic science article, they examined if this would influence subsequent judgment of credibility of a science article. These refutation texts supported people in overcoming these misconceptions and significantly affected their evaluation of subsequent text.

Additionally, the use of texts as a short intervention for epistemic change successfully changed dimensions of epistemic cognition in other studies. In Kienhues et al. (2011), participants were randomly assigned to read one of two different texts on DNA fingerprinting; the intervention text was based on research in conceptual change and refutation text, and included epistemic concerns about the science of DNA fingerprinting. Under this condition, participants in the experimental group showed greater epistemic change than those in the control group. These results supported their adaptation of conceptual change perspectives to changing epistemic beliefs, or the notion of epistemic conceptual change—that individuals have "misconceptions about the nature of knowledge, thinking, and reasoning that must be overcome" (Sinatra & Chinn, 2011, p. 276) and the use of previous research that demonstrated the efficacy of refutation texts in conceptual change (Diakidoy et al., 2003; as cited in Kienhues et al., 2008; Salisbury-Glennon & J. Stevens, 1999). Building off of this research, Porsch and Bromme (2011) tested the efficacy of what they called epistemological sensitization texts. This text highlighted comments on the epistemological nature of scientific facts, arguing that they should thus elicit a more advanced and evaluative view of knowledge. The researchers examined the effect of this text on participants' source numbers and appreciation in trying to answer a question using multiple texts and found that those with less advanced views saw positive epistemic change toward advanced views, while it had an unintended opposite effect for those with advanced views.

Prior studies that employed short, targeted refutation texts have generally used experimental designs with pre-post or post-only measures to detect epistemic change

(e.g., Kienhues et al., 2008; Flemming et al., 2020). Most used self-report instruments capturing beliefs along dimensions such as certainty, simplicity, and justification, often adapted from Hofer & Pintrich (1997). These interventions typically involved a single reading session, where participants read either a refutational or neutral text, followed by epistemic cognition measures. Similar to these studies, Experiment 1 in this dissertation uses a between-subjects design comparing the effects of a refutational text with a control text on topic-specific certainty beliefs about climate science. However, Experiment 1 expands on prior methods by including both immediate and delayed post-test measures, allowing assessment of sustained epistemic change. Additionally, unlike previous work focused primarily on abstract domains or general scientific reasoning, this study specifically targets epistemic beliefs within the context of climate science—an urgent and socially relevant topic.

Outcomes related to Epistemic Cognition

Bråten et al.'s (2011) integrated model has inspired several empirical studies examining the role of epistemic beliefs in multiple text comprehension, often using science-based topics (e.g., evolution, genetically modified foods). In these studies, researchers assessed participants' prior epistemic beliefs and measured their integration of multiple texts through summary writing, open-ended questions, or source-based inference tasks. For example, Bråten et al. (2014) found that students with more evaluativist epistemic beliefs were more likely to construct coherent, source-integrated representations when reading conflicting texts.

In alignment with this research, Experiments 2 and 3 in this dissertation examine how certainty and justification beliefs influence integration across texts presenting diverging perspectives on climate change. Experiment 2 tests whether a text-based intervention designed to shift certainty beliefs enhances participants' ability to construct integrated summaries. Experiment 3 further examines whether the act of engaging in integration itself fosters epistemic change, particularly among readers who are prompted to resolve contradictions through synthesis in an integrative writing task. These studies extend prior work by combining intervention and comprehension tasks and measuring both epistemic beliefs and integration quality within a single experimental framework.

The significance of epistemic cognition comes from theory and research linking different forms of epistemic cognition to desired knowledge and behavior. Researchers have argued that epistemic cognition is an important predictor of many learning outcomes

including online learning, self-regulated learning, scientific learning, critical thinking, use of source information in argumentation, and comprehension of single and multiple texts (Ferguson, 2015), and is therefore an important phenomenon to understand for improving learning. In a recent meta-analysis, Greene, Cartiff, and Duke (2018) completed a systematic analysis of the quantitative empirical research on epistemic cognition and academic achievement, which found a small but meaningful relationship between the two. The meta-analysis further supported domain-general, domain-specific, and topic-specific conceptualizations of epistemic cognition, as well as stronger correlations when the specificity of measures of epistemic cognition matched specificity of measures of achievement. Additionally, conceptual knowledge and argumentation performance were more strongly associated with epistemic cognition than declarative or procedural knowledge performance.

With regard to multiple text comprehension, previous studies have shown that holding adaptive epistemic beliefs is related to better multiple text comprehension and integration (e.g., Bråten et al., 2008; Strømsø et al., 2008). These studies have shown that different dimensions of epistemic beliefs, as defined by Hofer and Pintrich (1997), can be facilitative when readers try to build an integrated understanding across texts (Bråten, Britt, et al., 2011). Based on these studies and the role of epistemic cognition in multiple text comprehension demonstrated in many other studies (e.g., Afflerbach et al., 2013; Bråten et al., 2016; Rukavina & Daneman, 1996; Schommer, 1990), coupled with the increasing need for individuals to navigate and evaluate a plethora of written texts containing information, misinformation, and disinformation, it is clear that increased attention toward research at the intersection of epistemic cognition and multiple text comprehension is warranted.

Multiple Text Integration

Several models of text comprehension have contributed important developments that fed into the development of the integrated model of multiple text comprehension that is used in this study and should thus be reviewed. A commonality among models of both single and multiple text comprehension is the foundational use of Kintsch's Construction-Integration model (1988), which proposes that comprehension of text includes integration of the text's meaning (otherwise known as the textbase) with prior knowledge, to construct an interpretation of the situation that is described in the text (known as the situations model). This model assumes that there are several layers of mental representation that

are constructed throughout single text comprehension. These layers include a surface code (the exact words and sentences in the text), a textbase (the internal meaning of the text), a situation model (the interpretation of the situation described in the text) and text genre (the document type).

In addition to these representations for single texts, Britt et al. (1999) propose through their documents model of multiple text comprehension that, with multiple text comprehension, two additional levels of representation are constructed across texts. These two levels consist of the intertext model and the mental model. The intertext model includes source information for each text and facilitates global meaning by helping individuals remember which claims were made by which sources, while the mental model is the integrated representation of the situations being described across texts. By combining existing empirical evidence for the documents model with Hofer and Pintrich's theoretical model and epistemic cognition and through a review of empirical research, Braten et al. (2011) have proposed one cohesive model of epistemic cognition and multiple text comprehension.

The Integrated Model of Multiple Text Comprehension

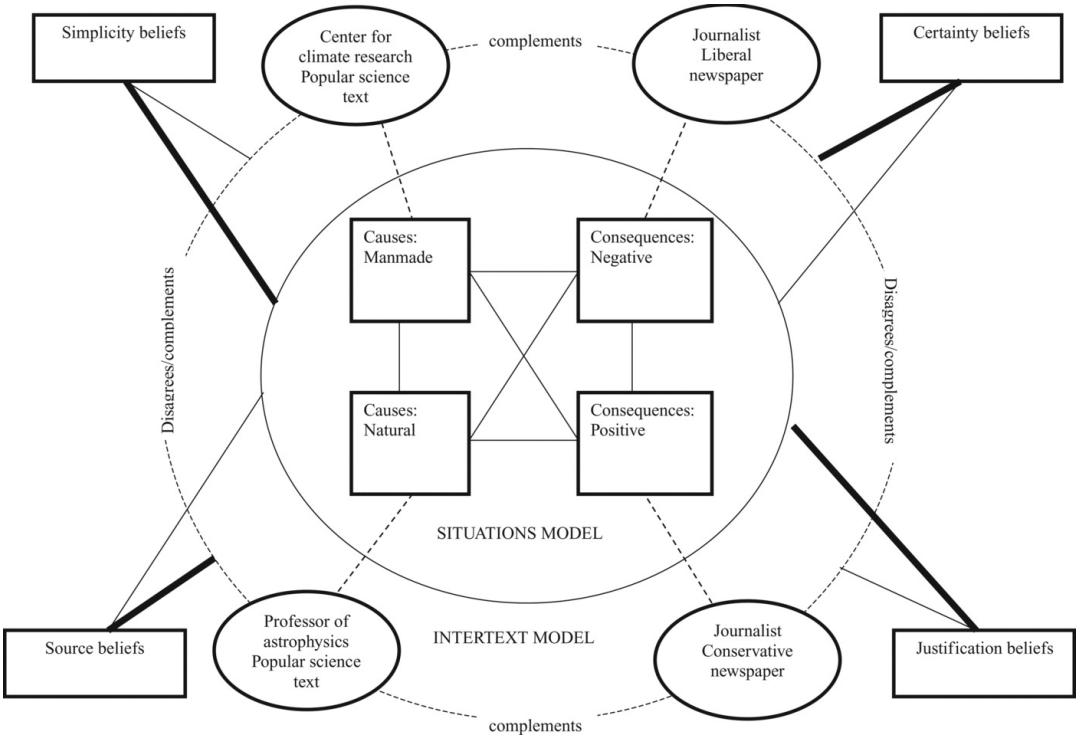
In the first comprehensive review of empirical links between epistemic belief dimensions and multiple text comprehension, Braten, Britt, Stromso, and Rouet (2011) evaluated the documents model and the cognitive processes than enable this comprehension. They then updated the documents model through a review of empirical evidence on epistemic beliefs and their role in multiple text comprehension to create an integrated model of multiple text comprehension, which provides the theoretical underpinnings for this dissertation. This model, integrating Hofer and Pintrich's (1997) model and Britt et al.'s (1999) documents model, proposes a link between the four dimensions of epistemic cognition proposed by Hofer and Pintrich with Britt et al.'s mental model and intertext model. Specifically, they hypothesized that simplicity and justification beliefs are most relevant for the development of a reader's mental model, while certainty beliefs and source beliefs are influential for intertext-model construction.

This model provided a theoretical basis for research demonstrating relationships between epistemic beliefs and multiple text comprehension. Moreover, it raised questions about the bi-directional relationship between epistemic cognition and multiple text comprehension, which has since been demonstrated in some studies (Ferguson, 2015). Research has shown that multiple text comprehension and integration tasks, which

correlate to epistemic beliefs, can themselves influence the development of advanced epistemic beliefs if those texts are divergent. Lastly, the model supports the use of short-term interventions to expedite developmental processes proposed by developmental psychologists for individuals to attain advanced epistemic beliefs. Bråten et al. (2011) note of their integrated model of multiple text comprehension, that "Although preliminary evidence indicates that interventions can effectively promote changes in epistemic beliefs, it remains to be seen whether such interventions may, in turn, affect students' multiple text comprehension positively, as suggested by our theoretical framework." Inspired by this, the following dissertation seeks to examine the efficacy of such an intervention and if it, in turn, affects students' multiple-text comprehension with regard to climate science.

Figure 1

Braten et al.'s (2011) integrated model of epistemic beliefs and documents model representation.



Note: The figure above shows Braten et al.'s (2011) integrated model of epistemic beliefs and documents model representation resulting from the reading of four different texts about climate change. As explained by the researchers, "The situations-model component consists of boxes and solid lines; the intertext-model component of ovals and broken lines. The strength of the links between the epistemic belief dimensions and the components of the documents model is represented by the thickness of the lines." (Bråten, Britt, et al., 2011, p. 57).

Prior Research Based on Braten et al.'s Integrated Model

Research grounded in the integrated model has shown that readers' epistemic beliefs—particularly beliefs about the certainty of knowledge and the justification for knowing—are significantly associated with their ability to select, evaluate, and integrate conflicting information across texts (Bråten & Strømsø, 2011; Strømsø et al., 2011). For example, readers with more advanced source and justification beliefs are more likely to recall source information, engage in corroboration, and distinguish between claims made by different authors (Bråten et al., 2009). These studies frequently used think-aloud protocols, open-ended integration tasks, and multiple-choice comprehension tests as measures.

Experiment 2 in this dissertation extends this line of research by testing whether an epistemic belief intervention prior to reading multiple texts influences how participants process, integrate, and respond to the texts. In contrast to prior studies that examined correlations between existing beliefs and integration outcomes, Experiment 2 uses an experimental design to manipulate beliefs and assess subsequent integration. Experiment 3 flips this approach: it investigates whether reading and integrating multiple texts can itself foster epistemic change, an idea rooted in the theoretical possibility of bidirectionality suggested by Bråten et al. (2011) and tested in a limited way by Ferguson (2015). Experiment 3 also includes a writing task to test the added benefit of expressive integration on epistemic development.

Hypothesis, Aims, and Objectives

The hypotheses tested in these studies are informed by the intricate relationship between the nature of climate change knowledge, epistemic beliefs, and multiple text comprehension and integration, based on existing theories and supporting research in these fields. These research questions have been slightly adjusted from the initial draft to align with changes in analysis procedures. For example, the decision to remove a pretest (as supported by a pilot study) changed the ability to conduct any within-subjects designs, meaning we could only comment on significant differences between groups and not the extent to which any changes happened. Otherwise, the research questions and hypotheses remain unchanged. By systematically examining these conjectures, I aim to explore how topic-specific epistemic beliefs influence understanding, engagement, and skepticism towards climate change. The research questions are as follows:

1. **Different Epistemic Beliefs through a Short Text Intervention:** Can a brief textual intervention about epistemic certainty in climate science lead to significant

differences in people's certainty beliefs? I hypothesized that the intervention would increase certainty compared to the control group, and that these differences would persist after one-week delay.

2. **Different Multiple Text Comprehension and Integration through a Short Text Intervention:** If there are significant differences resulting from the intervention, does that lead to better multiple-text comprehension and integration of climate information? I hypothesized that the intervention group would show better integration skills than the control group, thanks to their more adaptive epistemic stance.
3. **Different Epistemic Beliefs through Multiple Text Comprehension and Integration Activities:** Conversely, can engaging in multiple-text integration tasks lead to significant differences in epistemic certainty about climate science? I hypothesized that the intervention would increase certainty compared to the control group, and that these differences would persist after one-week delay.

Experiment 1 is grounded in Bendixen and Rule's (Bendixen & and Rule, 2004) process model of epistemic change and Hofer's (2000, 2001) multidimensional framework of epistemic beliefs. The research question tests whether a text-based intervention targeting certainty (a core epistemic dimension in Hofer's framework) can shift climate-specific epistemic beliefs. The hypothesis aligns with Bendixen and Rule's emphasis on resolution strategies, positing that targeted interventions can induce doubt and belief revision. Experiment 2 draws on the Documents Model Framework (Bråten, Britt, et al., 2011; Britt et al., 1999). It examines how epistemic belief interventions influence multiple text integration-a key focus of the Documents Model. Experiment 3 integrates Bendixen and Rule's model with the integrated documents model.

The hypotheses presented above will be scrutinized through empirical investigation over the course of three studies, contributing to the broader discourse on educational strategies, science communication, and policymaking in the contexts of both one of the most pressing socio-scientific issues of our time. The following three chapters separately detail each experiment's methodology, analysis, results, and conclusion. Chapter 3 details Experiment 1, Chapter 4 details Experiment 2, and Chapter 5 details Experiment 3. These chapters are followed by an overarching discussion of findings and conclusions in Chapter 6.

Chapter 3:
Investigating the Effects of a Short Text on Epistemic Beliefs

The initial aim of Experiment 1 was to examine if the use of a short-term, text-based intervention supports changes in certainty beliefs about knowledge in climate science, as proposed by several researchers who have suggested and explored the idea (e.g., Flemming et al., 2020; Kienhues et al., 2008; Porsch & Bromme, 2011). To accomplish this goal, an experiment was designed comparing the effect of reading one of two different texts, one experimental and one control, distributed randomly between two groups of research participants. Pilot study results supported changing the design from pre-post to post only, adjusting the aim of Experiment 1 to examine if the use of a short-term text-based intervention results in differences in epistemic beliefs. As part of this experiment, I also examined if there were changes after a delay. Moreover, because the refutation text specifically targeted the uncertainty dimension of epistemic cognition as defined by Hofer and Pintrich (1997), Experiment 1 also included exploratory analyses on the extent to which the text changed this dimension specifically, compared with others.

I hypothesized that if readers are explicitly given information about epistemic beliefs about climate change in the form of a refutation text, and then presented with the adaptive epistemic belief, then they will exhibit different and greater certainty beliefs about the nature of climate change than those who receive a control text. Moreover, I hypothesized that these differences would persist following a one-week delay.

Method

Sampling Procedures

Study Review

An initial application for the review of this whole research program was submitted to, reviewed by, and approved by the University of Minnesota Institutional Review Board through its Ethical Oversight Submission System (ETHOS), as this study constitutes social and behavioral research that involves human participants. The purpose is to ensure adequate protection and informed, uncoerced consent of participants (IRB ID STUDY00011972). An additional modification request was submitted following pilot and norming studies to seek review of changes to Experiment 1 research protocol resulting from the norming and pilot studies, which was also approved.

Recruitment

Participants were recruited using the online crowdsourcing platform Prolific, which facilitates participant recruitment, retention, and reimbursement for scientific studies. This platform was used to connect participants to the online research platform Qualtrics which facilitates research questions and tasks and allows for data collection for later analysis. Participants self-selected for participation in the study, which was conducted fully online. Participants received a total of ten dollars (eight and two dollars for Parts 1 and 2, respectively) as compensation for their participation in this two-part study.

Consent

Consent was obtained through Qualtrics. Before group assignment, everyone was first taken to a welcome page for the study and asked to provide consent. This page also informed participants the longitudinal nature of the study, explaining that they will be asked to participate in a second sitting of the study in one week that will provide additional compensation. Participants who did not consent were returned to Prolific without compensation. Appendix A provides the consent form used in this study.

Sample Size, Power, and Precision

A target sample size of 128 participants was set based on an a-priori power analysis, which indicated a minimum sample size of n = 128 to detect a small-to-medium effect (η = .25) with .80 power. To justify the assumed effect size for the present study's power analysis, we reviewed prior research on short-term epistemic belief interventions. Kienhues, Bromme, and Stahl (2008) reported small to moderate effects (Cohen's d = 0.37–0.61) in a study examining belief change following brief refutational and informational instruction. Flemming et al. (2020) found consistent positive effects of refutation texts on perceptions of scientific tentativeness and credibility across four experiments, suggesting a reliable moderate impact, though specific effect sizes were not always reported. Similarly, Kienhues, Stadtler, and Bromme (2011) observed significant changes in epistemic beliefs and decision-related variables following exposure to conflicting medical information, further supporting the potency of brief, targeted interventions. Based on this body of work, we conducted an a priori power analysis for ANCOVA using G*Power, assuming a moderate effect size (Cohen's f = 0.25), α = 0.05, and power (1–β) = 0.80, which is appropriate given the observed range of effects in similar intervention-based epistemic belief research.

Inclusion and Exclusion

The intent of this study was to examine if an experimental text on epistemic beliefs could be an effective intervention for the general population in changing certainty with respect to knowledge about climate science. As such, the study aimed to include a broad distribution of US adults (ages 18 and above) including variation across gender and race. All participants were fluent English speakers, given the experimental and control texts are in English; this was ensured through setting a recruitment filter in Prolific so that only fluent English speakers could see the study opportunity and volunteer to participate.

Participant Characteristics

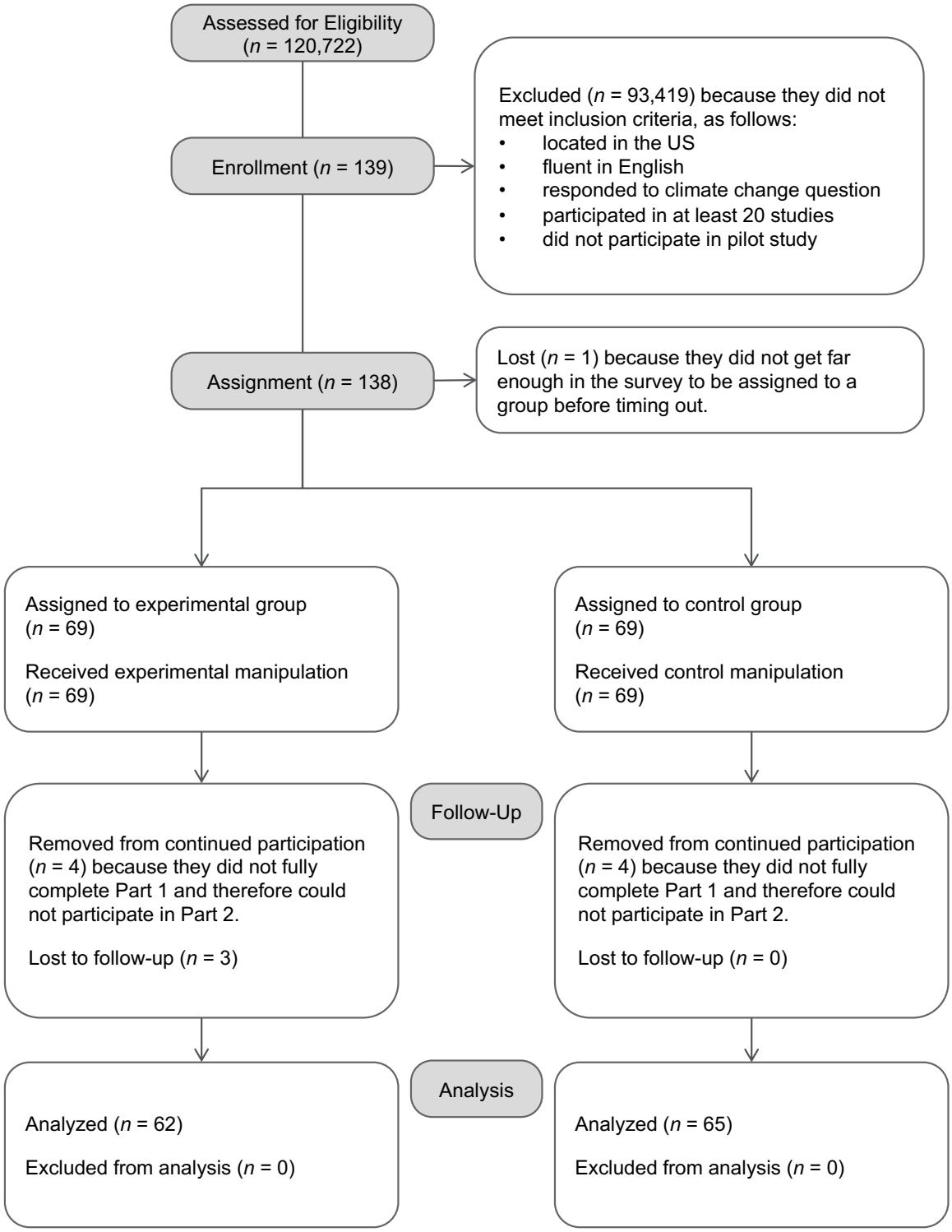
Initially, 139 participants responded to participate in the experiment. Nine participants did not complete the study (dropped out at various points in the study) and were removed from the final sample for analysis. Three did not complete the second part but were left in for primary analysis. The final participant pool consisted of 130 participants: 65 female, 65 male, 0 gender non-binary, M_{age} = 40 years, SD_{age} = 13 years, 77.7% White, 10.8% Asian, 5.4% Black, 4.6% More than one race/ethnicity and 1.5% Other.

Participant Flow

The flow of participants through each stage of Experiment 1 is depicted in Figure 2. All participants within the Prolific participant pool were assessed for eligibility. Only a subset of participants was eligible due to inclusion criteria, and only the necessary number of participants from within that pool participated in the study, volunteering on a first-come first-served basis. Two participants who enrolled timed out; Prolific sets a maximum allowed time for the study (67 minutes), based on the researcher's estimated completion time (20 minutes; the actual average was timed at 16 minutes). Any participants who didn't return to Prolific within the allotted time with the completion code were automatically timed out and ineligible for completion and compensation and replaced by another participant. All other participants were randomly assigned to the experimental or control condition by Qualtrics. Several participants were subsequently lost because they did not answer all questions or did not complete Part 2.

Figure 2

Flow of participants through each stage of Experiment 1.



Measures and Covariates

Primary measures

Primary measures collected for this study included the Topic Specific Epistemic Belief Questionnaire (Appendix B) and the Climate Change Concept Inventory (Appendix C). Both are previously developed, tested, and validated measures.

Topic-Specific Epistemic Belief Questionnaire. Bråten and Strømsø's (2009) topic-specific epistemic belief questionnaire (TSEBQ) which focuses on the topic of climate science was used as the measure of epistemic cognition in both Study 1 and Study 3 and can be found in Appendix B. This questionnaire was developed based on Hofer and Pintrich's (1997) theoretical model of epistemic cognition and originally consisted of 49 items before being revised to include 24. The TSEBQ includes 24 questions spanning the two hypothesized dimensions concerning knowledge about climate change (what one believes knowledge about climate change is like) which are certainty and simplicity, and two hypothesized dimensions concerning knowing about climate change (how one comes to know about climate change) which are source and justification. The breakdown is as follows: six questions for certainty, six items for simplicity, five items for source, and seven items for justification. The original bipolar Likert-type rating scale, with response options ranging from 1 (*strongly disagree*) to 10 (*strongly agree*) for each item, was presented, and items for simplicity and source dimensions were reverse-coded according to original design. The TSEBQ immediate post-test results were analyzed for reliability and was found to have good internal consistency, as determined by a Cronbach's alpha of 0.723. Each of the underlying dimensions, as defined through previous work validating the scale, had Cronbach's alpha values as follows: 0.897 (Certainty), 0.170 (Simplicity), 0.687 (Source), 0.762 (Justification).

Climate Change Concept Inventory. Prior knowledge of climate change concepts was selected to be included because prior knowledge of a domain or topic is widely assumed to have a relationship with epistemic beliefs about that domain or topic (Bråten & Strømsø, 2009; Muis et al., 2015). Bråten and Strømsø (2009) also developed a prior knowledge measure for climate science for the same study. However, after assessing the instrument for appropriateness for this program of research, it was deemed irrelevant for the current state of climate science and had too many items relating to outdated policy knowledge. As such, other scales were considered for use. However, many of these either lacked an examination of test validity or had limited external validity

(e.g., the scale was constructed for use with and validated for use with middle school students).

Ultimately, Libarkin et al.'s (2018) climate change concept inventory was selected for use as a measure of prior knowledge, for several reasons. This climate change concept inventory can be found in Appendix C. First, it was validated for use with the same population (a diverse population of adults, ages 18 to 75, with a mix of gender, race, religiosity, political affiliation, and education) in the same context (an online survey using a crowdsourcing platform). Second, it relatively short (21 items), enough to disseminate within the context of a multi-step online experiment. Third, it was recently developed and validated, and the climate science included in the measure is current. The climate change concept inventory results were analyzed for reliability and was found to have good internal consistency, as determined by a Cronbach's alpha of 0.702.

Secondary measures

Secondary measures were collected both automatically by Prolific and intentionally through survey design for this study and included fluent languages, ("Yes", "No", "Don't know"), age, ethnicity, highest level of education, and political affiliation (Appendix D and Appendix E).

Data Collection

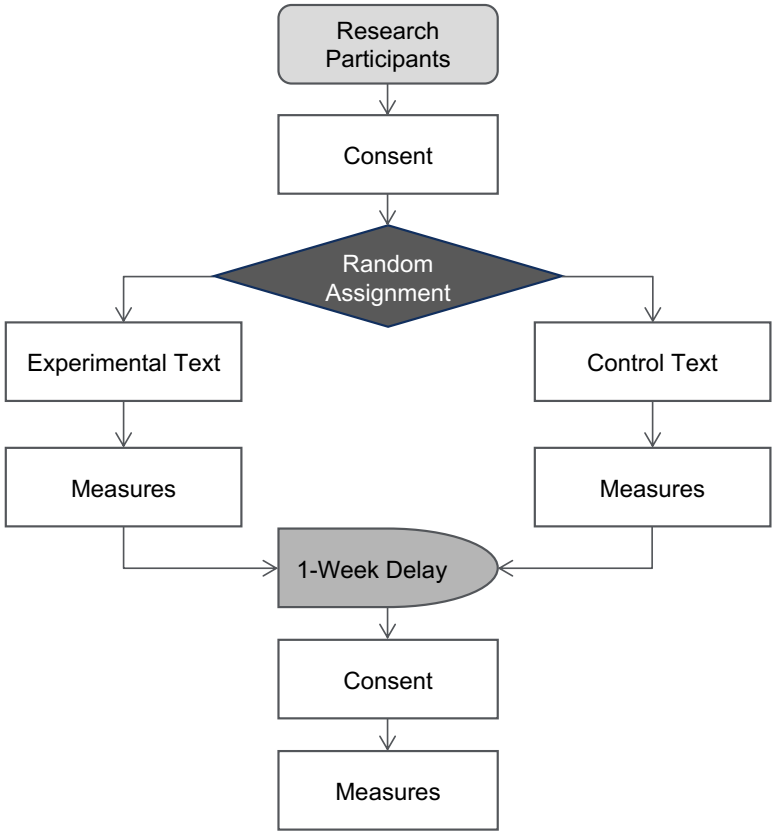
The data collection process is depicted in **Error! Reference source not found.**. P articipants completed the online surveys individually. For the first part of the two-part study, eligible participants were recruited through the online crowdsourcing platform Prolific through being shown this opportunity and some basic information. Participants who expressed interest were forwarded to Qualtrics where they were asked to provide consent. Next, participants who consented to participate were randomly assigned to either the experimental group or the control group and presented with the text according to random group assignment. They were given as much time as they wanted to complete this task. After reading the text, all participants were completed the 24-item topic specific epistemic belief questionnaire (TSEBQ), followed by the 21-item climate change concept inventory. They were given as much time as they needed to answer the questions. Finally, participants completed the demographics questions. Participants were also reminded that they would be able to opt into the delayed posttest on Prolific in one week and asked to remember to return to participate in the second half of the study within the following week.

A one-week delay between the intervention and follow-up assessment was chosen to evaluate the short-term stability of epistemic belief change, consistent with prior research on epistemic interventions and conceptual change. Kienhues et al. (2008) employed a two-week delayed posttest to examine the persistence of changes in epistemological beliefs following brief instructional exposure, finding that some shifts endured beyond the immediate session. While two weeks offers a medium-term window, a one-week delay has also been used in epistemic cognition research—for example, Bauman (2021) implemented a one-week delay to assess reductions in belief perseverance following a brief epistemic intervention. The one-week period strikes a balance: it is long enough to assess whether changes persist after initial processing and reflection, but short enough to reasonably attribute those changes to the intervention, rather than unrelated experiences. Thus, the one-week interval provides a theoretically and empirically grounded timeframe for detecting whether the epistemic effects of the intervention are not only immediate but also temporally durable.

The second part of the study was also set up in Prolific, limited to a specific Prolific participant list which, at first, had no participant IDs included. As participants completed part 1, each participant was noted and added to the list of Prolific participants following one-week delay. Participants who saw this invitation and opted in were forwarded to Qualtrics where they were asked to provide consent. Next, participants completed the 24-item TSEBQ, followed by a two-item subset of the climate change concept inventory. They were given as much time as they needed to answer the questions.

Figure 3

Updated Experiment 1 design



Masking

Participants were masked to the extent that (1) they were not aware that there were two conditions, and therefore, (2) they were not aware of the condition to which they had been randomly assigned. I administered the experimental manipulations, but this was randomized automatically through Qualtrics and not known until after completion of the experiment. Outcomes were assessed with knowledge of condition assignments.

Psychometrics

Assumption checks were conducted prior to confirmatory factor analysis (CFA). Results from the Henze-Zirkler test indicated a violation of multivariate normality, HZ = 1.00, $p < .001$, and all 24 variables failed univariate normality tests (Anderson-Darling, all $p < .001$). Despite this, no signs of problematic multicollinearity were detected (no pairwise correlations exceeded .90). The data were deemed factorable based on a high Kaiser-Meyer-Olkin (KMO) overall index of .83, with most individual measures of sampling adequacy above .70, and Bartlett's test of sphericity was significant, $\chi^2(276) = 1500.10$, $p < .001$.

A CFA was conducted using the robust maximum likelihood estimator (MLR) to account for non-normality. The model specified four latent constructs—Simplicity, Certainty, Source, and Justification—based on theoretical groupings of 24 items. Model fit was poor, $\chi^2(246) = 537.60$, $p < .001$, CFI = .78, TLI = .75, RMSEA = .096, SRMR = .120, suggesting the hypothesized structure did not adequately fit the data.

The Certainty and Justification factors exhibited strong, statistically significant loadings (standardized λs ranging from .63 to .90), supporting their construct validity. However, the Simplicity factor had inconsistent loadings, including several negative or weakly loading items (e.g., $\lambda = -.13$ to $-.66$), and Source also showed weak loadings overall. High modification indices suggested potential cross-loadings (e.g., item 23 on Simplicity and Certainty) and error covariances (e.g., between item 8 and item 10), implying potential conceptual overlap or measurement redundancy.

Taken together, these results suggest that while parts of the hypothesized factor structure were supported, others—particularly Simplicity and Source—may require item revision or model respecification. Further model testing with revised indicators, including possible exploratory factor analysis (EFA) or bifactor models, may improve fit and clarify structure. Standardized factor loadings indicating the strength of the relationship between each item and its associated factor are presented in Table 1.

Table 1

Standardized Factor Loadings for the Topic-Specific Epistemic Belief Questionnaire.

Factor	Item	Standardized Loading (λ)	SE	p
Simplicity	1	0.739	0.084	0
Simplicity	2	-0.13	0.102	0.2
Simplicity	3	0.437	0.12	0
Simplicity	4	-0.487	0.102	0
Simplicity	5	-0.661	0.088	0
Simplicity	6	0.718	0.072	0
Certainty	7	0.788	0.046	0
Certainty	8	0.754	0.047	0
Certainty	9	0.898	0.025	0
Certainty	10	0.878	0.028	0
Certainty	11	0.615	0.072	0
Certainty	12	0.677	0.078	0
Source	13	0.356	0.124	0.004
Source	14	0.749	0.066	0
Source	15	0.595	0.095	0
Source	16	0.706	0.088	0
Source	17	0.44	0.137	0.001
Justification	18	0.646	0.063	0
Justification	19	0.664	0.073	0
Justification	20	0.411	0.112	0
Justification	21	0.72	0.062	0
Justification	22	0.63	0.075	0
Justification	23	0.626	0.083	0
Justification	24	0.371	0.107	0.001

Conditions and Design

Experiment 1 used materials from previous studies on epistemic cognition (e.g., Bråten & Strømsø, 2009) and climate change knowledge (Libarkin et al., 2018), as well as new texts developed for this study following examples set forth by all research in the field published prior to this study's initiation (Flemming et al., 2020; Kienhues et al., 2008; Porsch & Bromme, 2011). These materials and types of materials have been successful in changing epistemic beliefs and measuring dimensions of epistemic cognition and prior knowledge; however, none of them have specifically targeted a dimension of epistemic

beliefs, nor have they studied the effects of an experimental text condition compared to a control text condition on topic-specific epistemic beliefs on climate change.

Intervention Texts

The intervention testing materials consisted of two informational texts, one that has been constructed for epistemic sensitization (experimental condition), and one that has not (control condition) (Appendix F and Appendix G). The decision to use the term "epistemic sensitization text" reflects several decisions. First, it follows in the footsteps of Porsch and Bromme (2011), who used research on refutation text to guide their intervention, which they called epistemological sensitization texts. Second, while the structure of the text follows literature on refutation text, the decision to not use the term "refutation text" comes from the epistemic, and not conceptual, nature of these beliefs. While there can be a series of epistemic beliefs that are considered "scientifically supported" as being better or worse than other epistemic beliefs as they relate to different, associated tasks (e.g., academic tasks, acquiring new knowledge) they do not hold similar statuses in terms of correct or incorrect, the way conceptual beliefs can. Instead, what is scientifically supported in terms of epistemic beliefs is the relative adaptiveness or utility of having certain beliefs over others (Sinatra et al., 2014).

These texts were developed iteratively through several rounds of testing in norming studies. They were first developed by following text structures used in prior research that were successfully able to prompt conceptual change (e.g., Kendeou et al., 2014). Initially, three short texts were developed; two control texts were used to explore the effects of having a text on the same topic (climate change) that did not have refutation in it, and one that did. Each text began with an introductory section. Following this, participants read a sentence explicitly acknowledging the misconception. This is followed by a refutation cue, and an explanation for why alternative epistemic stances are incorrect. The text ends with a closing sentence. Following each norming study, both texts were adapted based on findings. The final two texts were ultimately longer than initially built, with a slightly different structure, although they still followed the same basic structure of introduction, misconception, refutation/explanation, and closing.

For each iteration of text development, apart from differences on addressing epistemic beliefs about climate science, the two texts were created to be as equivalent as possible. The texts were constructed such that comprehensibility and complexity were similar. This was done first by ensuring that the texts were similar in length (same number

of sentences, with each paragraph length and the whole text length being within five words' difference between the two texts). Additionally, the texts were examined for comprehensibility using Flesch-Kincaid Grade Level and Flesch Reading Ease scores, both to ensure that the texts were at a high school reading level, and that the two tests were scored similarly in readability (Table 2). While the goal of text construction was to keep both grade level and reading ease lower than where they ended up, the use of terms such as "epistemic cognition" made this task difficult, and so the priority became to ensure the texts were as equal as they could be.

Table 2

Comparison of construction of two final texts used in Experiment 1

		Experimental	Control
Readability	Flesch-Kincaid Grade Level	13.7	12.9
	Flesch Reading Ease	37.2	38.3
Word Count	Total	794	817
	¶ 1	69	75
	¶ 2	60	54
	¶ 3	45	63
	¶ 4	175	180
	¶ 5	82	76
	¶ 6	115	86
	¶ 7	115	135
	¶ 8	124	139

Note. This table includes descriptive statistics of the two final texts used in Experiment 1.

The Flesch Reading Ease Test rates text on a 100-point scale. The higher the score, the easier it is to understand the document. The formula for the Flesch Reading Ease score is 206.835 – (1.015 x ASL) – (84.6 x ASW), where ASL is the average sentence length (the number of words divided by the number of sentences) and ASW is the average number of syllables per word (the number of syllables divided by the number of words). The Flesch-Kincaid Grade Level test rates text on a U.S. school grade level. For example, a score of 8.0 means that an eighth grader can understand the document. The formula for the Flesch-Kincaid Grade Level score is: (.39 x ASL) + (11.8 x ASW) – 15.59.

Norming studies to refine texts. Two rounds of norming procedures were used to understand people's trust in the text, as well as to identify any sources of confusion in the text.

First norming study. The first round of norming was done just to get an idea for how people would respond to initially conceptualized experimental and control texts. In the first round of norming, 45 participants from Amazon MTurk responded to a six-item survey that included one of three texts through random selection. Each participant was asked to answer three Likert-type rating scales on a four-point scale (4 = Very, 3 = Moderately, 2 = Slightly, 1 = Not at all) (Table 3). Appendix H contains the survey used in this first norming study. Results presented in Table 3 indicate that on average, participants felt high certainty about anthropogenic climate change across all three conditions (3.19, 3.62, and 3.44 for the experimental, control 1, and control 2 texts respectively, indicating moderate to high certainty), indicating that the experimental text was not supporting greater certainty than the control. Additionally, while respondents found the text to be believable (3.12, 3.62, and 3.06 for the experimental, control 1, and control 2 texts respectively, indicating moderate to high certainty), trustworthiness scores were a bit lower (2.88, 3.38 and 2.88 for the experimental, control 1, and control 2 texts respectively, indicating slight to moderate certainty). These results indicated that while the texts may have been working as intended in terms of believability, they needed to be adjusted to be more trustworthy to truly test the effects of the intervention and the experimental text needed to demonstrate greater certainty.

Table 3

Norming Study 1 Rating Scale Item Results

Text	Sample Size	Certainty		Trust		Belief	
	n	*M*	*SD*	*M*	*SD*	*M*	*SD*
Experimental	16	3.19	1.047	2.88	1.088	3.12	1.025
Control 1	13	3.62	.870	3.38	.870	3.62	.870
Control 2	16	3.44	.892	2.88	.957	3.06	.892

Participants were also asked to qualify their responses to the three questions through an open-ended question asking them to explain their choice. Results based on the Likert-type rating scales alone were not the focus of this norming study; instead, the focus was to pair these responses with open-ended responses to understand people's

perceptions of the text, in order to adjust anything that was distracting readers from the focus of the intervention, which was to discuss certainty of climate change (Table 4). Once qualitative responses were coded into themes, only one clear pattern of feedback emerged, which was that some participants questioned the source of the text which distracted them from its credibility.

Table 4

Norming Study 1 example qualitative responses

Topic	Frequency	Example Responses
Source Credibility	11	"The text seems consistent with things I've read in the past. However, I don't recall seeing any sources or links to reputable websites in this particular text. Therefore, I will only say I moderately trust the text." "I have not looked further to clarify that this is, indeed, a reliable source. It sounds legitimate, but I'd like to hear it from other sources too." "The text did not reference any credible sources. Anyone could have written it for any purpose they deemed necessary." "The information seemed credible, although sources were not cited."

Because it was noted by multiple participants that the lack of an explicit source was distracting, it was decided that a neutral source would be selected in the subsequent norming study. A science museum website was selected based on prior research indicating that the greatest share of people who identify as conservative, as well as the greatest share of people who identify as liberal, selected science and technology centers or museums as a trustworthy news source among all other common news sources (e.g., documentaries, science magazines, government agencies, news outlets, science podcasts/radio) (Funk et al., 2017). Once the texts were adapted to appear as though they

were pages on identical science museum websites, the norming study was rerun, this time just focusing on participants' understanding of the experimental text.

Second norming study. In the second round of norming, 24 participants from Amazon Mturk responded to a thirteen-item survey that included reading the same experimental text as the first norming study, now displayed to look like it came from a fictitious science museum website (see Appendix I). The purpose of this norming study was to investigate if putting the experimental text in the context of a source would change the way respondents comprehend the text. The thirteen-item survey included six questions specifically targeting insight into perceived believability, credibility, and comprehensibility of text. Each participant was asked to answer two Likert-type rating scales and four open-ended questions. Additionally, participants were first asked to respond to the seven-item subset of the Topic-Specific Epistemic Belief Questionnaire pertaining to the dimension of certainty (see Appendix B). Participants were asked to reflect on aspects of the text that provided difficulty in comprehension or created additional distractions. Appendix I contains the survey used in this second norming study.

High-level findings from respondents who found the text to be untrustworthy or not believable can be found below (Table 5). By and large, most participants only had positive reflections about the text. However, results of norming study 2 indicated that for participants who questioned the trustworthiness and believability of the text, these reflections were tied to a lack of references and a lack of information in the text. As a result, the design was modified slightly so that an additional, complex topic with relative certainty (genetically modified organisms, or GMOs) was introduced to first describe the misconception, refutation cue, and explanation regarding adaptive epistemic beliefs. This was done in order to provide more information on epistemic beliefs and provide a more thorough explanation of epistemic cognition, an unfamiliar concept.

Table 5

Norming Study 2 example qualitative responses

Topic	Frequency	Example Responses
Please explain why you selected [your choice] for the question "To what extent, if at all, do you believe what the article is saying?".		
Please explain why you selected [your choice] for the question "To what extent, if at all, do you trust that the article you read is a reliable source of information?".		
Do you find that the article does this effectively? Please explain why or why not. For reference, the article is provided again below.		

Lack of references	3	"No citation to factual study results. Just reference to them. This is just an article."
		"The article did not give sources but it did mention things that are already a part of what I have heard discussed in the past.
		"It helps, but brings little resources to the argument. Citation would help in any factual statements proving they are indeed factual."
		"I think it gave some good examples to look into but having sources for the information and stats would lead to a more effective article."
Lack of details	3	"I think it gives some information but would need to know more details."
		It seems like a reliable source since it is well written and states facts that I have previously heard. But, I'd have to do more research on whoever wrote the article."
		"I do believe some of what they are saying is true but I would need to know more to fully believe it."
		"I think it did a good job but more could be added."
What could be improved in this article?		
Add some references		"Make some specific references to studies and data since the 1800s illustrating the points they are making."
		"It needs more stats and sources."
		"There could be citations and links to some of the research that was mentions."

Third norming study. The texts revised because of norming study 2 were used in a third norming study with 15 participants. The procedure was identical to the second norming study, with the exception of the texts themselves (see Appendix I for the procedure and Appendix F and Appendix G for the experimental and control texts, respectively). All but one said that the text was very or moderately trustworthy and all but one said "yes" when asked if the text was believable. Eight participants (53%) said the text does not need any revisions, and two others (13%) said that they are not sure what else could be done to improve it. Recommendations from the other five respondents (33%) included adding citations and authors, both of which could not be done due to the intent of the study. To the researcher, this confirmed the text was working as intended and no

other significant changes needed to be made. This revision was used in the pilot study and retained in the final procedure for all three experiments.

The initially proposed design for Experiment 1 was similar to the mixed design employed by Kienhues et al. (2008) in their study that examined changes to epistemic beliefs between pretest and posttest between two groups, each assigned a different text. The initial study design for Experiment 1 was a mixed-design, with epistemic beliefs as the within-subjects factor (assessed three times during the study) and text type as the between-subjects factor (whether participants are provided with the epistemic sensitization text (experimental group) or not (control group)). The design was intended to examine changes to the epistemic beliefs measure from baseline to posttest and delayed posttest in each group. However, in order to confirm the study design prior to experiment data collection, a pilot study was first conducted to confirm this decision.

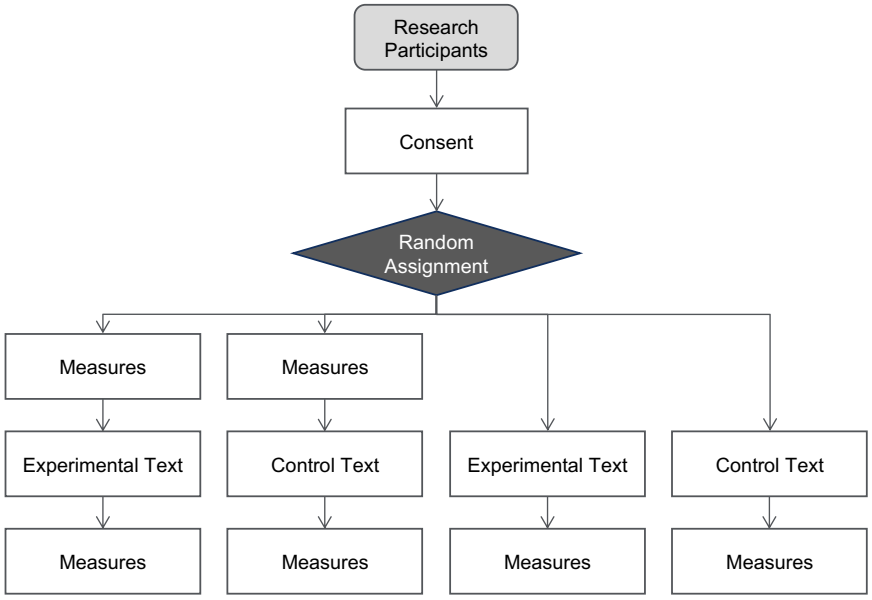
Pilot Study to Confirm Experiment 1 Design

Initially, a two-group, pretest-posttest design was proposed in order to examine individual changes to certainty beliefs following reading the text. A pretest-posttest design was preferred, as these designs are effective for controlling threats to internal validity, such as selection bias, history, maturation, regression to the mean, and instrumentation (Daily, 2017; Sawilowsky, 1996). However, given the theoretical framework of the experiment (that explicitly introducing the notion of epistemic beliefs and common incorrect epistemic beliefs, followed by refuting them with correct epistemic beliefs, would lead to epistemic change) as well as the nature of the epistemic beliefs measure (which is quite explicit in asking about epistemic beliefs), there was concern that the certainty beliefs measure may pose a threat to external validity through pretest sensitization. The concern was that allowing participants to read the certainty beliefs measure would (1) decrease the responsiveness of experimental group participants to the experimental text, and/or (2) increase the responsiveness of control group participants to the posttest measure.

Therefore, to determine whether to employ this design as intended, an on four-group design was piloted with forty participants (ten participants in each group) to explore the potential effects of the pretest on intervention efficacy (see Figure 4). An initial review of descriptive statics of the results revealed that pretest sensitization was affecting the dependent measure. Appendix J contains the survey used in this pilot study.

Figure 4

Pilot study design.



Results of the pilot study indicated that there may be a qualitative difference in the experience of readers who first read the epistemic beliefs measure from those who didn't (see Table 6). For participants who saw the epistemic beliefs measure prior to reading the experimental text, certainty beliefs were similar (M = 5.31 and M = 4.77 for Experimental and Control groups, respectively) as expected from randomization. The mean certainty belief score was similar after as well, indicating the intervention may not have an effect. However, when the same study was run on another random sample without the pretest, certainty beliefs were different (M = 3.51 and M = 5.58 for Experimental and Control groups, respectively) supporting the hypothesis that the experimental text may be effective, and that the epistemic beliefs questionnaire may have impacted people's reading.

Table 6

Pilot study results

Group	Text	Sample Size (*n*)	Pre-Test Certainty (*M*)	Post-Test Certainty (*M*)
A	Experimental	10	5.60	5.31
B	Control	10	4.85	4.77
C	Experimental	10	--	3.51
D	Control	10	--	5.58

Pilot study results indicated that the pretest may be impacting participants in the control group, specifically, their perception of the experimental text and subsequent posttest results. For this reason, the study design was changed from the initially proposed mixed design to a between-subject design, without the use of a pretest. The target study sample size was recalculated and increased to adjust for this change.

Data Diagnostics

Planned data diagnostics included peri-data-collection assessment of completion of Parts 1 and 2. It was determined ahead of time that participants who did not fully complete both parts of the study would not be included in analysis, although those that completed Part 1 (defined as “answered a majority of questions across all pages in the survey) would be compensated for their time. Throughout the course of data collection, eight participants did not complete both parts of the study and were removed from the final sample for analysis.

For this study, no data imputation was performed. Participants were strongly encouraged to complete every item, and any participants who did not complete an item were excluded from analysis. Any outliers in the data would be identified by standardized residuals greater than ±3 standard deviations. Analyses will be conducted including and excluding outliers, in order to examine the effects of outliers on findings and understand if any outliers are changing the nature of the findings. Data transformations were only undertaken to meet assumptions for statistical inference, where appropriate. For analyses herein, assumptions included normal distribution and homoscedasticity, in addition to a lack of outliers.

Analytic Strategy

The strategy for inferential statistics in this experiment was to compare two groups, experimental and control, using experimental design through blind randomization of intervention assignment with a large sample to ensure power. To protect results from experimentwise error given planned secondary analysis, a Bonferroni adjustment was applied.

Results

In this section, I begin by presenting analysis undertaken to compare the experimental condition to control condition with respect to prior topic knowledge. Next, I describe analysis on the effects of the text intervention on participants' beliefs about epistemic cognition long-term. Lastly, I describe analysis of epistemic beliefs after controlling for certainty beliefs. A final section discusses the results in the context of each research question.

Primary Analysis

Prior to conducting the ANCOVA, the data were examined for violations to assumptions. Results of evaluation of the assumptions were satisfactory, as follows. There was a linear relationship between the climate change concept inventory and topic specific certainty beliefs for both the experimental and control, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(1, 126) = 0.221$, $p = 0.639$. Standardized residuals for the interventions were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). Standardized residuals for the overall model were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). There was homoscedasticity, as assessed by visual inspection of the standardized residuals plotted against the predicted values.

In this first analysis, we used topic-specific certainty beliefs measured at posttest as the dependent variable, and climate change knowledge as a covariate. After adjustment for climate change knowledge, there was a statistically significant difference in certainty beliefs between the intervention and control, $F(1, 127) = 11.349$, $p < .001$, partial $\eta^2 = .082$. Using adjusted means, the epistemic belief score was greater in the control group ($M = 5.33$, $SE = 0.25$) compared to the experimental group ($M = 4.12$, $SE = 0.25$) (see Table 7).

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Table 7

Experiment 1 estimated marginal means after controlling for prior knowledge.

			95% Confidence Interval	
Text	Mean	Std. Error	Lower Bound	Upper Bound
Experimental	4.12	0.25	3.62	4.62
Control	5.33	0.25	4.83	5.83

Secondary Analysis

In an additional set of analyses, an ANCOVA was run to determine the effect of the experimental text on topic-specific epistemic knowledge as measured by delayed posttest score, after controlling for immediate posttest scores and climate change knowledge.

Prior to conducting the mixed ANCOVA, the data were examined for violations to assumptions. There was a linear relationship between pre- and post-intervention TSEBQ score for both groups, as assessed by visual inspection of a scatterplot. Standardized residuals for the interventions were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). Standardized residuals for the overall model were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). There was homoscedasticity, as assessed by visual inspection of the standardized residuals plotted against the predicted values. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p = .409$). After adjustment for climate change knowledge and immediate posttest scores, delayed posttest certainty beliefs differed between the control group ($M = 4.46$, $SE = .17$) and the experimental group ($M = 4.99$, $SE = .18$). There was a statistically significant difference in delayed posttest scores between experimental and control, $F(1, 123) = 4.49$, $p = .036$, partial $\eta^2 = .035$ (Table 8).

Table 8

Experiment 1 unadjusted average certainty belief scores at post-test and delayed post-test

Text	Sample Size (n)	Post-Test TSEBQ (M)	Delayed Post-Test TSEBQ (M)
Experimental	62	4.08	4.47
Control	65	5.37	4.96

Exploratory analysis

A one-way multivariate analysis of covariance (MANCOVA) was conducted to examine whether epistemic beliefs differed between the experimental and control groups across four dimensions (certainty, simplicity, source, and justification), after controlling for prior climate change knowledge. Assumptions were checked prior to analysis. Box's test of equality of covariance matrices was not significant, $p = .739$, indicating homogeneity of covariance matrices across groups. Levene's tests for equality of error variances were non-significant for three of the four dependent variables ($p > .05$), except for the source dimension ($p = .046$), suggesting generally acceptable homogeneity of variances.

There were no violations of normality, and visual inspections of residual plots did not indicate heteroscedasticity. After adjusting for climate change knowledge, the multivariate test showed a statistically significant difference between groups on the combined dependent variables, Wilks' $\Lambda = .895$, $F(4, 124) = 3.64$, $p = .008$, partial $\eta^2 = .105$. Follow-up univariate tests revealed that this group difference was primarily attributable to the certainty dimension of epistemic beliefs, $F(1, 127) = 11.35$, $p < .001$, partial $\eta^2 = .082$. There were no statistically significant differences between groups on simplicity, source, or justification (all $p > .05$).

Adjusted means are presented in Table 9. The experimental group reported lower scores on the certainty dimension ($M = 4.08$, $SD = 2.08$) than the control group ($M = 5.37$, $SD = 2.03$), consistent with a more uncertainty-embracing epistemic profile. Scores on the other dimensions were relatively similar across groups. These findings suggest that the intervention specifically influenced beliefs about the certainty of knowledge without broadly affecting other aspects of epistemic cognition.

Table 9

Estimated marginal means and standard deviations for TSEBQ dimensions by condition, controlling for prior knowledge

TSEBQ Dimension	Experimental (n=65)	Control (n=65)
Certainty	4.08 (2.08)	5.37 (2.03)
Simplicity	5.39 (0.99)	5.32 (0.94)
Source	4.80 (1.85)	5.02 (1.47)
Justification	7.96 (1.11)	7.73 (1.21)

Discussion

Support of Original Hypotheses

To examine research question 1, “Can a brief textual intervention about epistemic certainty in climate science lead to significant differences in people’s certainty beliefs?”, an ANCOVA was performed to analyze the effectiveness of the epistemic sensitization text compared with the control text on participants’ measures of topic-specific certainty beliefs, using the prior knowledge measure as a covariate. The purpose of this analysis was to look at differences between groups to investigate whether there was statistically significant difference between the experimental condition and the control condition. Using adjusted means, the epistemic belief score was statistically, significantly greater in the control group. Results of the ANCOVA and descriptive statistics indicate that participants in the experimental condition had lower topic-specific certainty belief scores after reading their assigned text than those participants in the control group, supporting the hypothesis that the experimental text may be effective in promoting more certain epistemic beliefs around anthropogenic climate change. These results enabled subsequent analyses determining if there was any support for persistence in changes to certainty beliefs after delay and exploring if these changes were to just the one dimension of epistemic certainty, or across multiple dimensions of epistemic beliefs. Additionally, a statistically significant result here indicates that the research program can continue to Experiments 2 and 3, which test the impact of reading such texts on multiple document comprehension.

To answer the research question for secondary analysis, “Did the results persist after a one-week delay?”, an ANCOVA was performed to analyze whether certainty beliefs were statistically significantly different between experimental and control after a one-week delay, controlling for prior knowledge and immediate posttest score. Results of the ANCOVA again indicated that participants in the experimental condition had statistically significantly different certainty beliefs after one-week delay, after controlling for prior knowledge and initial beliefs measures taken after reading. Therefore, persistence in changes to certainty beliefs are supported using this intervention.

Finally, to answer the research question for exploratory analysis, “Did epistemic beliefs change for the certainty dimension only?”, exploratory analysis was conducted to examine differences across the four epistemic belief dimensions. Results of the MANCOVA and descriptive statistics indicate that participants in the experimental condition did not demonstrate statistically significant differences in other dimensions of

epistemic beliefs, when compared with participants in the control condition, after controlling for prior knowledge. This supports the idea that if the experimental text was successful in efforts to specifically target change participants' certainty beliefs about climate change, the two participant groups were otherwise equivalent, and the experimental text was successful as intended.

Similarity of Results

Comparably brief interventions have been shown to influence beliefs about other epistemic concerns such as intelligence and learning (Dweck, 1999; Gill et al., 2004; Torsney et al., 2021). However, prior research using interventions targeting epistemic beliefs about knowledge in different domains and topics is lacking, save a few studies (e.g., Braten et al., 2022). The findings from this study that topic-specific beliefs about epistemic certainty can be influenced by a brief text intervention using a refutation text approach suggests that such an approach may be used to promote adaptive epistemic certainty on a specific topic in the context of reading and learning.

Interpretation

This study is the first in a series of three to try and address the intersection of epistemic beliefs, multiple document literacy, and refutation text with a specific focus on the certainty dimension of epistemic beliefs and made a step in the direction of addressing whether a short text intervention would result in different certainty beliefs, relative to a control text. Through adapting a refutation text approach typically applied to correct misconceptions relating to conceptual knowledge, we demonstrated that such an approach can lead to differences in certainty beliefs compared to a control condition. Moreover, results indicated that participants who read the intervention text were more certain about anthropogenic climate change, as intended. This an important finding given the promise of brief text interventions to support adaptive certainty beliefs for educational purposes.

Results also indicated that reading a short intervention supported changes to certainty beliefs in the long-term after controlling for prior knowledge. This was a surprising finding, given the intervention was only applied once and was very brief. Study three, as described in detail in Chapter 5, investigates one of the next steps to these findings, which is whether a brief intervention coupled with a task testing multiple documents literacy may promote sustained change long-term.

Lastly, results from investigating the exploratory research question indicated that differences in epistemic beliefs were narrowly focused on the dimension of certainty beliefs, as intended. This is important given differing theories on the extent to which the dimensions of epistemic beliefs are interrelated, with some researchers hypothesizing that that selective change of one dimension is less likely (Schommer, 1990).

Generalizability

While this study was intentionally developed to maximize generalizability through controlling all variables possible and using experimental design, there are still elements that impact external validity. The contextual issues that impact generalizability of this study apply to all three studies and are therefore discussed further in Chapter 6.

Implications

Experiments 2 and 3 in this research program test whether the findings of this study go beyond its effects on participants' beliefs about epistemic justification to impact participants' performance on multiple document literacy tasks concerning a specific topic, that being climate change. This would be consistent with prior research as well as theoretical frameworks hypothesizing the role of epistemic beliefs, and specifically, the role of certainty beliefs, in multiple document literacy (Bråten et al., 2011; List & Alexander, 2019). A thorough discussion of implications is provided in Chapter 6.

Chapter 4:

Investigating the Effects of a Short Text on Multiple Text Integration

The aim of Experiment 2 was to examine if the use of the short-term, text-based intervention from Experiment 1 results in differences in multiple text integration. To accomplish this goal, an experiment was designed comparing the effect of reading one of two different texts, one experimental and one control, distributed randomly between two groups of research participants. I hypothesized that if readers are explicitly given information about certainty of knowledge within the topic of climate change in the form of a refutation text, and then presented with the adaptive epistemic belief, then they will integrate multiple texts on climate change differently from those who receive a control text.

Method

Sampling Procedures

Study Review

An initial application for the review of this whole research program was submitted to, reviewed and approved by the University of Minnesota Institutional Review Board through its Ethical Oversight Submission System (ETHOS), as this study constitutes social and behavioral research that involves human participants. The purpose is to ensure adequate protection and informed, uncoerced consent of participants (IRB ID STUDY00011972). An additional modification request was submitted following Experiment 1 to seek review of changes to research protocols for Experiments 2 and 3 resulting from Experiment 1 results, which was also approved.

Recruitment

Participants were recruited using the online crowdsourcing platform, Prolific, which facilitates participant recruitment, retention, and reimbursement for scientific studies. This platform was used to connect participants to the online research platform Qualtrics which presents research questions and tasks and allows for data collection for later analysis. Participants self-selected for participation in the study, which was conducted fully online, and received ten dollars as compensation for their participation in this two-part study.

Consent

Consent was obtained through Qualtrics. Before group assignment, everyone was first taken to a welcome page for the study and asked to provide consent. Participants who did not consent were returned to Prolific without compensation. Appendix A provides the consent form used in this study.

Sample Size, Power, and Precision

A target sample size of 100 participants was set based on an a-priori power analysis, which indicated a minimum sample size of n = 100 to detect a moderate effect (η = .25) with .70 power due to resource limitations. To determine the sample size and interpret results, we assumed a moderate effect size (Cohen's f = 0.25) based on prior research using similar designs in the multiple-text comprehension literature. Studies investigating epistemic interventions and source-based reasoning often use mixed factorial designs to examine how instructional conditions (e.g., refutation texts, epistemic prompts) interact with task characteristics or topic conditions across multiple comprehension outcomes (e.g., Barzilai & Zohar, 2012; Bråten et al., 2014; Stadtler & Bromme, 2014). These studies have reported small to moderate effects on open-ended measures of integration and source evaluation—particularly when assessing within-subjects shifts in reasoning across different text types or controversies.

Because the initially designed study used a 2×2 mixed design with both between-subjects (intervention) and within-subjects (task condition) manipulations, and includes two theoretically related but distinct dependent variables, a moderate effect size (Cohen's f = 0.25) was selected for power analysis and model planning (equivalent to $\eta^2 \approx 0.06$, or Cohen's d ≈ 0.5 for main effects). This estimate is appropriate given the design's sensitivity to interaction effects and the expressive nature of the outcome variables, which typically exhibit higher variance than recognition-based measures but are better suited to capturing nuanced epistemic reasoning. Once the study design was changed based on the Experiment 1 pilot study, sample sizes were left unchanged at the expense of power due to resource limitations.

Inclusion and Exclusion

The intent of this study was to examine if an experimental text on epistemic beliefs can impact multiple text comprehension. As such, the study aimed to include a broad distribution of US adults (ages 18 and above) including variation across gender and race. All participants were fluent English speakers, given the experimental and control texts are in English; this was ensured through setting a recruitment filter in Prolific so that only fluent English speakers could see the study opportunity and volunteer to participate.

Participant Characteristics

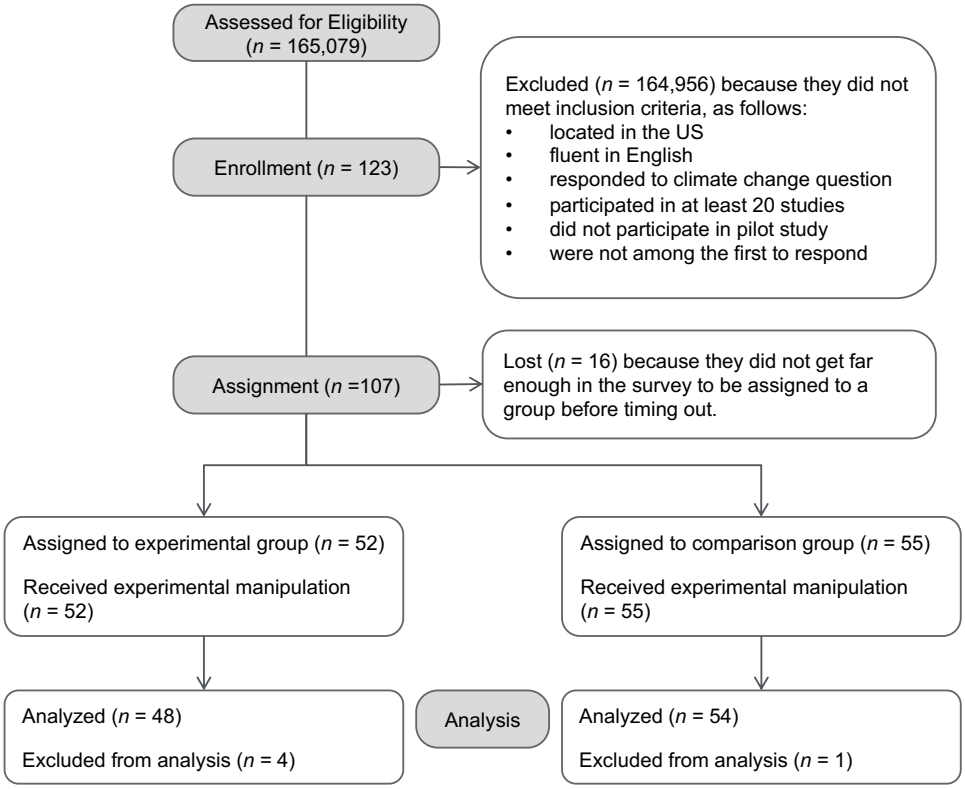
The final participant pool included 49 female and 50 male individuals. One participant selected prefer not to say. The mean age of participants is, M_{age} = 41.17 years, SD_{age} = 12.25 years. The participant race/ethnicity demographics are as follows.64.7% White, 7.8 % Asian, 16.7 % Black, 5.9 % More than one race/ethnicity, and 4.9 % Other.

Participant Flow

The flow of participants through each stage of Experiment 2 is depicted in Figure 5. All participants within the Prolific participant pool were assessed for eligibility. Only a subset of participants was eligible due to inclusion criteria, and only the necessary number of participants from within that pool participated in the study, volunteering on a first-come first-served basis. Two participants who enrolled timed out; Prolific sets a maximum allowed time for the study (67 minutes), based on the researcher's estimated completion time (20 minutes; the actual average was timed at 16 minutes). Any participants who didn't return to Prolific within the allotted time with the completion code were automatically timed out and ineligible for completion and compensation and replaced by another participant. All other participants were randomly assigned to the experimental or control condition by Qualtrics.

Figure 5

Flow of participants through each stage of Experiment 2.



Measures and Covariates

Primary measures

Primary measures collected for this study included the Expressive Multiple Text Comprehension Measure (Appendix M) and the Receptive Multiple Text Comprehension Measure (Appendix N).

Multiple text integration measures. Following prior research on multiple text comprehension, including those examples set forth by Rukavina and Daneman (1996) and Braten et al. (2014), this study used two multiple text comprehension measures. Two different measures were selected based on tasks used in prior research, which broadly fit into categories of expressive and receptive tasks (Primor & Katzir, 2018). In this research, tasks that required writing or providing oral accounts of comprehension were classified as expressive tasks, whereas tasks that demanded marking a correct response were referred to as receptive tasks.

Expressive task. The expressive task consisted of three open-ended, short essay questions that can be found in Appendix M. Initially, this research proposed the use of three researchers for independently scoring responses. Given unanticipated costs for

participant recruitment, a decision was made to instead use a combination of human (manual) scoring and the use of two large language models to independently assess qualitative responses based on rubrics, the latter of which has been shown to have high precision (Zhang et al., 2024). Any disagreements will be resolved through manual review by me, with subject matter experts consulted for those items that required further consideration.

Receptive task. The receptive task consisted of 21 true-or-false questions that can be found in Appendix N. Each question required participants to integrate information from a specific pair of the seven provided texts. Every item was designed to assess whether participants could accurately comprehend and relate content across two distinct sources, resulting in full coverage of all 21 possible text pairings. This approach allowed for a systematic examination of participants' ability to recognize cross-textual consistency, contradictions, or complementary information, reflecting a core aspect of multiple text comprehension.

Secondary measures

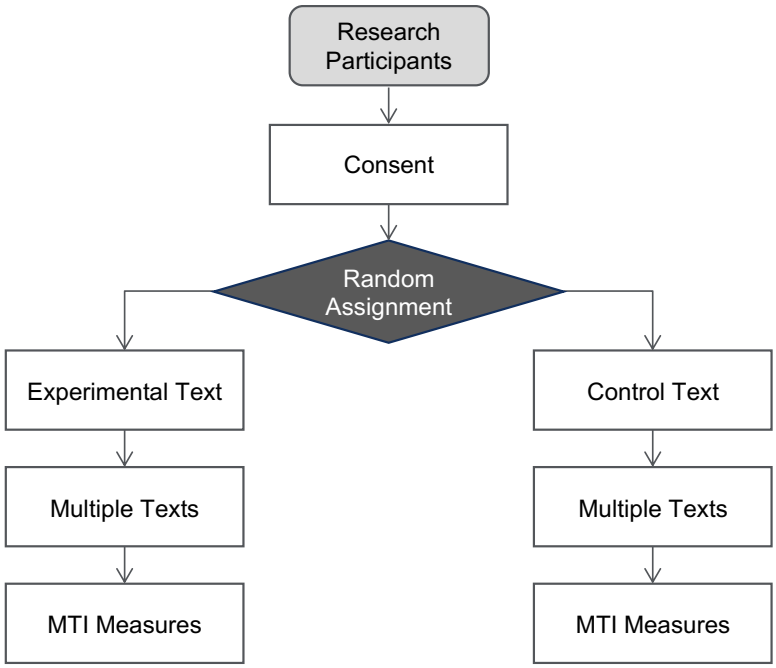
Secondary measures were collected both automatically by Prolific and intentionally through survey design for this study and included fluent languages, belief in climate change ("Yes", "No", "Don't know"), age, ethnicity, highest level of education, and political affiliation (Appendix D and Appendix E).

Data Collection

The data collection process is depicted in Figure 6. Participants completed the online study individually. Eligible participants were recruited through the online crowdsourcing platform Prolific through being shown this opportunity and some basic information. Participants who expressed interest were forwarded to Qualtrics where they were asked to provide consent. Next, participants who consented to participate were randomly assigned to either the experimental group or the control group and presented with the text according to random group assignment. They were given as much time as they needed to complete this task. After reading the texts, all participants were asked to complete (in order) the expressive MTI task, the receptive MTI task, and demographic questions. They were given as much time as they needed to answer the questions.

Figure 6

Experiment 2 Design.



Masking

Participants were masked to the extent that (1) they were not aware that there were two conditions, and therefore, (2) they were not aware of the condition to which they had been randomly assigned. Text assignment was randomized automatically through Qualtrics and not known until after completion of the experiment. Outcomes were assessed with knowledge of condition assignments.

Psychometrics

The results of both dependent variables were analyzed for reliability using Cronbach's Alpha. The receptive task had good internal consistency, as determined by a Cronbach's alpha of 0.718. The expressive task did not demonstrate good internal consistency, as determined by a Cronbach's alpha of 0.506.

Given the qualitative nature of the expressive task, additional care had to be taken in interpretation of responses and translation into quantitative results.

Conditions and Design

Experiment 2 used materials from previous studies on epistemic cognition (e.g., Bråten & Strømsø, 2009) and climate change knowledge (Libarkin et al., 2018), as well as new texts developed for this study following examples set forth by all research in the

field published prior to this study's initiation (Flemming et al., 2020; Kienhues et al., 2008; Porsch & Bromme, 2011). These types of materials have been successful in changing epistemic beliefs and measuring dimensions of epistemic cognition and prior knowledge; however, studies on short-term interventions have not specifically targeted a dimension of epistemic beliefs, such as the dimension of certainty tested in this experiment. Additionally, prior research with these materials has not explored the effects of an experimental text condition compared to a control text condition on topic-specific epistemic beliefs about climate change.

Intervention Texts

The intervention testing materials consisted of two informational texts, one that was constructed for epistemic sensitization (experimental condition), and one that was not (control condition) described in Chapter 3.

Multiple Texts

Participants in both groups read seven separate texts (Appendix L) about different aspects of climate change, as follows:

- The first text was a 574-word text from Cambell Biology a college-level textbook on biology (Urry et al., 2021). This text (Text A) explained anthropogenic climate change and the importance of global models.
- The second text was a 244-word op-ed published by Fox News (Haskins, 2023). This text (Text B) focused on sowing doubt about climate change by focusing on areas that have experienced a decrease in temperature.
- The third text was a 350-word news post taken from the Intergovernmental Panel on Climate Change (2021). This text (Text C) summarizes an IPCC report on the estimates of chances of temperature increased in the near future.
- The fourth text was a 401-word text about climate change obtained from *Integrated iScience*, a middle-school level textbook (Anderson et al., 2017). This text (Text D) discusses both positive and negative impacts of global warming.
- The fifth text was a 299-word text by the National Oceanic and Atmospheric Administration (2021). This text (Text E) presents the causes and effects of climate change.
- The sixth text was a 433-word news article published by the New York Times (Rosen, 2021). This text (Text F) describes the history of climate change and data collected over time to support that it is happening in neutral terms.

- Finally, the seventh text was a 441-word article published by the Washington Post (Mooney & Osaka, 2023). This text (Text G) discusses the disagreement between scientists about the pace of climate change.

One of the articles presented neutral information on climate change (Text E). Three of the articles (Texts B, D, and G) try to present climate change as uncertain in different ways. Three others (Texts A, C, and F) try to address public uncertainty by explaining causes of variation in climate change. These texts present different views on the causes of climate change (anthropogenic versus natural), the consequences of climate change (only negative versus a mix of negative and positive), and different views on the extent to which humans should address or mitigate climate change. These texts were selected because (a) the participants were likely to have some, but not extensive, prior knowledge of the topic; (b) the texts represented different kinds of authentic source materials that educated adult readers typically encounter; and (c) the discussion of this highly topical scientific phenomenon from multiple perspectives, because of its strong individual and social implications, was likely to elicit interest and reflection on the part of readers.

Each of these texts is an excerpt from a much longer text that was shortened for the purposes of this study. Participants were told that “The texts may have been adapted only to shorten the length of the article without changing the meaning.” Each text was presented on a separate page of the survey, and the source, author’s name and credentials, and date of publication were omitted on purpose to eliminate biased interpretation based on source information. However, participants were told prior to reading that “Each text is an article from one of the following resources: science museum, scientific government agency website, scientific school textbook, scientific news article”. The seven texts were presented to the participants in random order. Once each article was presented, participants were given an opportunity to review them again in any order they preferred.

Data Diagnostics

Planned data diagnostics included peri-data-collection assessment of completion of the study. Participants were strongly encouraged to complete every item, and any participants who dropped out and therefore did not complete one or more items were excluded from analysis Throughout the course of data collection, twenty-seven participants did not complete the study and were removed from the final sample for analysis. For this study, no data imputation was performed. Any outliers in the data were

identified by standardized residuals greater than ±3 standard deviations. Analyses were conducted including and excluding outliers, in order to examine the effects of outliers on findings and understand if any outliers are changing the nature of the findings. Data transformations were only undertaken to meet assumptions for statistical inference, where appropriate. For analyses herein, assumptions included normal distribution and homoscedasticity, in addition to a lack of outliers.

Analytic Strategy

The strategy for inferential statistics in this study was to compare two groups, experimental and control, using experimental design through blind randomization of intervention assignment with a large sample to ensure power. Because there were two outcomes of interest, a one-way multivariate analysis of variance (MANOVA) was used. To protect results from experimentwise error given post hoc ANOVAs following the MANOVA, a Bonferroni adjustment was applied.

Results

In this section, I begin by presenting analysis undertaken to compare the effects of the text intervention on participants' multiple text integration. A final section discusses the results in the context of each research question.

Primary Analysis

A one-way multivariate analysis of variance (MANOVA) was run to determine the effect of the intervention on multiple text integration. Two measures of multiple text integration were assessed: an expressive task and a receptive task. Participants were randomly sorted into one of two groups: experimental text (intervention) and control text (control). Preliminary assumption checking revealed that data was normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$); there were no univariate or multivariate outliers, as assessed by boxplot and Mahalanobis distance ($p > .001$), respectively; there were linear relationships, as assessed by scatterplot; no multicollinearity ($r = .393$, $p = .002$); and there was homogeneity of variance-covariance matrices, as assessed by Box's M test ($p = .003$).

A one-way MANOVA was conducted to examine whether there were statistically significant differences between groups (control vs. intervention) on a linear combination of two dependent variables: receptive and expressive multiple text integration scores. The multivariate effect was not statistically significant using Pillai's Trace, $V = .120$, $F(2, 77) = 2.49$, $p = .090$, partial $\eta^2 = .06$. This indicates that the intervention did not have a

statistically significant multivariate effect on the combined outcomes of receptive and expressive integration. However, the effect size suggests a small to moderate multivariate effect.

Although the overall MANOVA was not statistically significant, follow-up univariate analyses of variance (ANOVAs) were conducted to explore the effects of group membership on each outcome separately. For receptive task scores, the ANOVA was not significant, $F(1, 100) = 0.40$, $p = .528$, $\eta^2 = .004$, with a small effect size, $d = 0.13$. Similarly, for expressive task scores, the group difference was also nonsignificant, $F(1, 100) = 0.19$, $p = .664$, $\eta^2 = .002$, $d = –0.09$. These results indicate that the intervention did not produce statistically or practically significant differences in either form of integration performance when examined independently.

In summary, there was no statistically significant multivariate effect of the intervention on participants' receptive and expressive multiple text integration scores. Follow-up analyses likewise revealed no significant differences between groups for either outcome, with very small effect sizes for both variables. These findings suggest that the intervention, as implemented, did not have a measurable impact on multiple text integration performance.

Discussion

Support of Original Hypotheses

The purpose of Experiment 2 was to answer the following research question: Can a text-based intervention that targets climate-change-specific epistemic beliefs change multiple text integration? The results did not provide statistically significant support for the original hypothesis that a brief epistemic sensitization text would enhance participants' multiple text integration performance compared to a control text. Although the study was designed to test whether explicitly addressing adaptive certainty beliefs about climate change would help participants integrate information from multiple, divergent texts, the MANOVA and subsequent univariate ANOVAs revealed no significant differences between the experimental and control groups on either receptive or expressive multiple text integration scores. The effect sizes were small and non-significant, indicating that the intervention did not produce measurable improvements in participants' ability to integrate across texts when each form of integration was examined independently. Thus, while the intervention was successful in shifting certainty beliefs in Experiment 1, these changes did not translate into enhanced multiple text comprehension or integration in Experiment 2,

suggesting that a single, brief intervention does not affect the ability to integrate information from several texts and may not be sufficient to impact more complex literacy outcomes.

Similarity of Results

Previous research has demonstrated that individuals' epistemic cognition is predictive of multiple text comprehension and integration (e.g., Bråten, Britt, et al., 2011; Rukavina & Daneman, 1996). However, few studies have experimentally tested whether interventions targeting epistemic change can influence multiple text integration (Cartiff et al., 2021). One notable exception is Bråten et al. (2022), which used an intervention focused on the justification dimension of epistemic beliefs and found statistically significant effects. The limited number of experimental studies in this area highlights a gap in the literature that the present research seeks to address—specifically, whether brief interventions targeting epistemic uncertainty can impact comprehension and integration of conflicting texts about climate change.

Interpretation

This study is the second in a series of three aimed at exploring the intersection of epistemic beliefs, multiple document literacy, and the use of refutation texts. It takes a step toward addressing whether a brief, text-based intervention can influence how individuals comprehend and integrate information from multiple sources. Participants read seven texts representing divergent perspectives on climate change and responded to a series of expressive and receptive comprehension tasks. While the intervention was theoretically grounded and methodologically consistent with previous research on epistemic cognition, the results did not yield statistically significant differences between groups on the combined or individual outcome measures.

Several factors may explain the lack of statistically significant findings. First, potential sources of bias—particularly in participant recruitment—may have influenced results. Individuals recruited through Prolific's online panel tend to be more experienced survey respondents and may exhibit higher baseline levels of media literacy or familiarity with climate discourse than the general population. This could reduce the observable impact of a brief intervention, especially if participants already hold relatively sophisticated or entrenched epistemic beliefs.

Second, the study's measurement protocol may have introduced imprecision. Although the open-ended expressive questions were scored using carefully developed

rubrics, there is inherent variability in interpreting and coding qualitative data. In addition, while the receptive task used structured scoring, it may not have been sensitive enough to capture more nuanced shifts in how participants reconciled conflicting information across sources. The alignment between the intervention's goals and the expressive/receptive tasks may have been imperfect, limiting the capacity to detect subtle changes in integration strategies or epistemic stances.

Third, the study involved multiple outcome measures—MANOVA tested both receptive and expressive scores, followed by individual ANOVAs. While appropriate given the correlated nature of the dependent variables, this approach does introduce concerns about statistical multiplicity and the potential for Type I or Type II errors. No adjustments were made for multiple controls in follow-up tests, though no significant effects were found regardless. Furthermore, some overlap in what the expressive and receptive measures captured (e.g., understanding causal relationships or contrasting perspectives) may have contributed to shared variance that was not cleanly partitioned across tasks.

Finally, sample size constraints posed a meaningful limitation. While the study was powered to detect moderate effects, it likely lacked sufficient power to detect small but meaningful differences—especially given the subtlety of the intervention and the complexity of the cognitive processes being measured. The decision to prioritize a broad, text-rich reading experience over repeated measurement or longer interventions reflects real-world tradeoffs in resource availability. However, this decision also limits the precision and confidence with which null findings can be interpreted. A larger sample would have provided greater power for detecting subtle effects and enabled more granular subgroup analyses (e.g., by baseline belief strength or prior knowledge). However, given the small effect sizes observed in the current study, the lack of statistically significant group differences likely reflects genuinely modest impacts of the intervention rather than a power limitation.

In sum, the null results of this study may not necessarily indicate that epistemic interventions have no effect on multiple text integration. Rather, they underscore the complexity of designing and detecting such effects—particularly in brief interventions targeting deep, belief-laden domains. These findings reinforce the need for robust measurement, sensitive designs, and theory-informed approaches that consider both the content and context of belief change efforts.

Generalizability

While this study was intentionally developed to maximize generalizability through controlling all variables possible and using experimental design, there are still elements that impact external validity. The contextual issues that impact generalizability of this study apply to all three studies and are therefore discussed further in Chapter 6.

Implications

A thorough discussion of implications is provided in Chapter 6.

Chapter 5:

Investigating the Effects of Multiple Text Tasks on Epistemic Beliefs

The overarching aim of Experiment 3 was to examine if multiple text integration has an effect on epistemic beliefs, as proposed by the documents model framework (Bråten et al., 2011) through the mechanisms described by Bendixen and Rule (2004). To accomplish this goal, an experiment was conducted comparing the epistemic beliefs of groups that stopped at various points in the Experiment 2 procedure in order to explore the effects of multiple text reading and integration tasks on participants who read the experimental text. I examined if being tasked to read multiple texts about climate science leads to differences in certainty beliefs about climate science. I also examined if integrative (both receptive and expressive) writing exercises after multiple text reading led to differences in epistemic beliefs about climate change, particularly as it relates to the certainty of climate science. Additionally, I examined if any detected changes persisted after 1-week delay. Finally, Experiment 3 included exploratory analysis looking specifically at contrast analyses based on primary analysis results.

Because multiple text comprehension tasks are thought to have a bidirectional relationship with epistemic beliefs (Bråten et al. 2011), where multiple text comprehension and integration tasks can change one's epistemic beliefs just as tasks can be influenced by one's epistemic beliefs, a third study examined the effects of reading multiple texts and integrating texts to respond to the questions. The purpose was to parse apart the contributions of such tasks from Experiment 2. To examine the effects of multiple text comprehension and written integration tasks on epistemic cognition above and beyond the contributions of reading an epistemic sensitization text, participants were randomly assigned to one of four groups. It was hypothesized that multiple text comprehension and integration would each uniquely contribute to epistemic change, above and beyond any changes through the epistemic sensitization text.

Method

Sampling Procedures

Study Review

An initial application for the review of this whole research program was submitted to, reviewed by, and approved by the University of Minnesota Institutional Review Board through its Ethical Oversight Submission System (ETHOS), as this study constitutes social and behavioral research that involves human participants. The purpose is to ensure

adequate protection and informed, uncoerced consent of participants (IRB ID STUDY00011972). An additional modification request was submitted following Experiment 1 to seek review of changes to Experiment 2 and 3 research protocols resulting from the identification and modification of the seven texts and the development of the multiple text integration receptive task, which was also approved.

Recruitment

Participants were recruited using the online crowdsourcing platform Prolific, which facilitates participant recruitment, retention, and reimbursement for scientific studies. This platform was used to connect participants to the online research platform Qualtrics which facilitates research questions and tasks and allows for data collection for later analysis. Participants self-selected for participation in the study, which was conducted fully online. Participants received a total of eleven dollars (nine and two dollars for Parts 1 and 2, respectively) as compensation for their participation in this two-part study.

Consent

Consent was obtained through Qualtrics. Before group assignment, everyone was first taken to a welcome page for the study and asked to provide consent. This page also informed participants the longitudinal nature of the study, explaining that they will be asked to participate in a second sitting of the study in one week that will provide additional compensation. Participants who did not consent were returned to Prolific without compensation.Appendix A provides the consent form used in this study.

Sample Size, Power, and Precision

This study was designed to include a minimum of 180 participants. To guide sample size planning and statistical interpretation, we assumed a moderate effect size (Cohen's f = 0.25), in line with prior short-term intervention studies on epistemic belief change. Existing research has demonstrated that brief instructional interventions—such as refutation texts (e.g., Kendeou et al., 2014), belief sensitization activities (e.g., Kienhues et al., 2008), or conflicting information exposure (e.g., Kienhues, Stadtler, & Bromme, 2011)—can produce small to moderate effects on both domain-specific and task-specific epistemic beliefs, especially when combined with source-based reasoning or reflective writing.

The initial design included four experimental conditions and a pre–post repeated-measures component, which increases the precision of estimated effects and statistical power to detect within- and between-group differences over time. Although observed effect

sizes in the literature often range from d = 0.30 to 0.60 (approximately f = 0.15 to 0.30), a moderate effect size (Cohen's f = 0.25, or partial $\eta^2 \approx 0.06$) was selected as a conservative and realistic estimate of the magnitude of change based on prior findings.

In addition, this study models a mediating process—conceptually grounded in models of epistemic change and conceptual integration (e.g., Bråten et al., 2014; Stadtler & Bromme, 2014)—to examine how the intervention influences downstream comprehension or reasoning outcomes. Prior research suggests that epistemic beliefs can influence comprehension indirectly through task-level perceptions or integration processes (Barzilai & Zohar, 2012). Given the novelty and complexity of this mediation component, a moderate effect size provides a prudent estimate for detecting both direct and indirect effects in this context. Once the study design was changed based on the Experiment 1 pilot study, sample sizes were left unchanged at the expense of power due to resource limitations.

Inclusion and Exclusion

The intent of this study was to examine the effects of (1) the multiple texts used in Experiment 2 and (2) the multiple texts integration tasks used in Experiment 2 on changing epistemic beliefs of those who had already undergone the intervention of the experimental text from Experiment 1. As such, the study aimed to include a broad distribution of US adults (ages 18 and above) including variation across gender and race. All participants were fluent English speakers, given the experimental and control texts are in English; this was ensured through setting a recruitment filter in Prolific so that only fluent English speakers could see the study opportunity and volunteer to participate.

Participant Characteristics

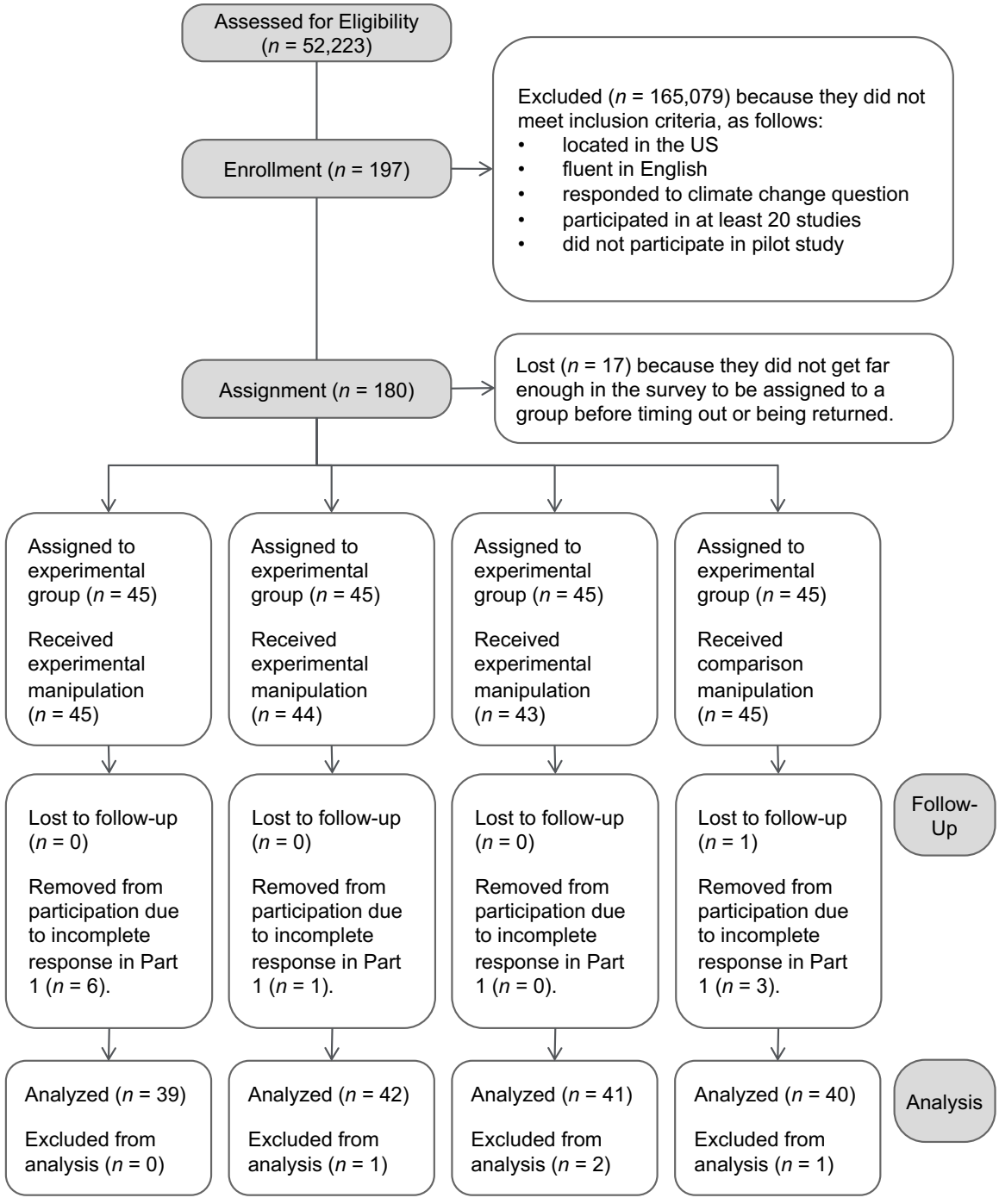
Initially, one hundred and ninety-seven participants responded to participate in the experiment. During part one, twenty-nine participants either timed out or were returned to Prolific due to unacceptable responses to consent and commitment request questions. Five participants were successful according to Prolific standards, but review of data showed that they did not complete the study sufficiently and were removed from the final sample for analysis. The final participant pool consisted of 162 participants with the following characteristics: 73 female, 88 male, 1 prefer not to say, M_{age} = 41 years, SD_{age} = 13 years, 61.1% White, 17.9% Black, 9.9% Asian, 6.2% Mixed, 4.9% Other.

Participant Flow

The flow of participants through each stage of Experiment 3 is depicted in Figure 7. All participants within the Prolific participant pool were assessed for eligibility. Only a subset of participants was eligible due to inclusion criteria, and only the necessary number of participants from within that pool participated in the study, volunteering on a first-come first-served basis. Seventeen participants who enrolled either timed out or returned because they didn't meet the qualifications. One hundred and eighty participants were randomly assigned to one of the four conditions by Qualtrics. Over the course of data collection, seventeen additional participants were dropped due to failure to complete the study, failure to return for Part 2, or missing data (e.g., a participant failed to respond to an entire measure). Thus, the final sample size was n = 163 participants.

Figure 7

Flow of participants through each stage of Experiment 3.



Measures and Covariates

Primary measures

Primary measures collected for this study included the Topic Specific Epistemic Belief Questionnaire (Appendix B) and the Climate Change Concept Inventory (Appendix C) from Experiment 1.

Secondary measures

Secondary measures were collected both automatically by Prolific and intentionally through survey design for this study and included fluent languages, belief in climate change (“Yes”, “No”, “Don’t know”), age, ethnicity, highest level of education, and political affiliation (Appendix D and Appendix E).

Data Collection

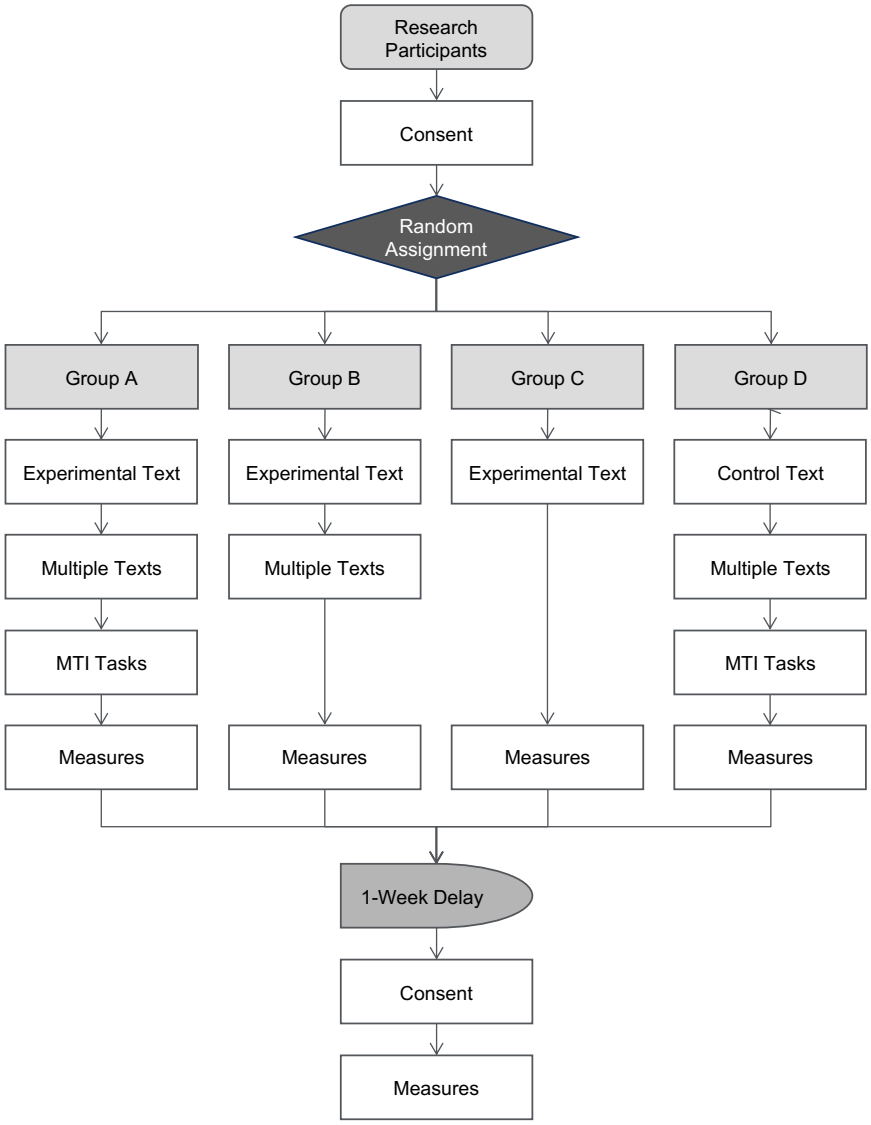
The data collection process is described in Appendix P. Participants completed the online surveys individually. For the first part of the two-part study, eligible participants were recruited through the online crowdsourcing platform Prolific through being shown this opportunity and some basic information. Participants who expressed interest were forwarded to Qualtrics where they were asked to provide consent. Next, participants who consented to participate were randomly assigned to one of four groups and presented with either the experimental text (Groups A, B, and C) or control text (Group D) according to random group assignment. They were given as much time as they wanted to complete this task. After reading the text, Groups A, B, and D were asked to read the same set of seven texts described in Experiment 2. Only Groups A and D were then asked to carry out the expressive and receptive tasks. Participants in Groups B and C had fewer tasks, which made their participation shorter; however, they were not given filler tasks, as the purpose of this study was to test certainty beliefs immediately after intervention(s). All groups then completed the 24-item topic-specific epistemic belief questionnaire (TSEBQ), followed by the 21-item climate change concept inventory. They were given as much time as they needed to answer the questions. Finally, participants completed demographics questions (Appendix E). Participants were also reminded that they would be able to opt into the delayed posttest on Prolific in one week and asked to remember to return to participate in the second half of the study.

The second part of the study was also set up in Prolific, limited to a specific Prolific participant list which, at first, had no participant IDs included. As participants completed part 1, each participant was noted and added to the list of Prolific participants following

one-week delay. Participants who saw this invitation and opted in were forwarded to Qualtrics where they were asked to provide consent. Next, participants completed the 24-item TSEBQ, followed by a two-question subset of the climate change concept inventory. They were given as much time as they needed to answer the questions.

Figure 8

Experiment 3 Design.



Masking

Participants were masked to the extent that (1) they were not aware that there were four conditions, and therefore, (2) they were not aware of the condition to which they had been randomly assigned. I administered the experimental manipulations, but this was

randomized automatically through Qualtrics and not known until after completion of the experiment. Outcomes were assessed with knowledge of condition assignments.

Psychometrics

The TSEBQ results were analyzed for reliability (overall and for each dimension) using Cronbach's Alpha. Topic-Specific Epistemic beliefs as an overall scale had low internal consistency, as determined by a Cronbach's alpha of 0.675. Each of the underlying dimensions, as defined through previous work validating the scale, had Cronbach's alpha values as follows: 0.867 (Certainty), 0.409 (Simplicity), 0.796 (Source), 0.785 (Justification).

A confirmatory factor analysis (CFA) was conducted to test a four-factor model of epistemic beliefs, including Simplicity, Certainty, Source, and Justification. The model was estimated using robust maximum likelihood (MLR) with full information maximum likelihood (FIML) to handle missing data. The analysis was based on 163 complete cases, with minimal missingness across the 24 observed indicators. Assumptions were checked prior to analysis. The data violated assumptions of multivariate normality (Henze-Zirkler test $p < .001$), and all items failed univariate normality tests. However, the Kaiser-Meyer-Olkin (KMO) measure indicated acceptable sampling adequacy (overall MSA = .77), and Bartlett's test of sphericity was significant, $\chi^2(276) = 1820.76$, $p < .001$, supporting the appropriateness of factor analysis.

Model fit was suboptimal. Although the scaled chi-square statistic was significant, $\chi^2(246) = 649.76$, $p < .001$, model fit indices suggested poor to mediocre fit: robust CFI = .744, TLI = .713, RMSEA = .101 (90% CI [.090, .111]), and SRMR = .125. These values fall outside commonly accepted thresholds for good fit, indicating that the model may not fully capture the latent structure of the data. Modification indices suggested potential cross-loadings and residual correlations, especially between items from Simplicity and Justification, that could improve model fit with further refinement.

Despite issues with overall fit, most items loaded significantly on their respective factors, offering partial support for the theorized structure. Standardized loadings for Certainty and Source were consistently strong (λs = .630–.800), while Justification showed acceptable loadings for most items (λs = .516–.780), except TSEBQ_J5 (λ = .213). Simplicity demonstrated the most variability, with strong loadings for TSEBQ_S1 (λ = .742) and TSEBQ_S6 (λ = .872), but non-significant or negative loadings for TSEBQ_S2 and TSEBQ_S4. These results suggest that while the overall factor structure is plausible,

certain indicators—particularly in the Simplicity and Justification factors—may require revision to improve measurement validity. Standardized factor loadings indicating the strength of the relationship between each item and its associated factor are presented in Table 10.

Table 10

Standardized Factor Loadings

Factor	Item	Loading	SE	p-value
Certainty	1	0.766	0.043	0
Certainty	2	0.63	0.065	0
Certainty	3	0.758	0.061	0
Certainty	4	0.741	0.05	0
Certainty	5	0.713	0.049	0
Certainty	6	0.726	0.053	0
Simplicity	7	0.742	0.059	0
Simplicity	8	-0.115	0.107	0.282
Simplicity	9	0.596	0.068	0
Simplicity	10	-0.224	0.113	0.048
Simplicity	11	-0.445	0.1	0
Simplicity	12	0.872	0.042	0
Source	13	0.68	0.072	0
Source	14	0.8	0.064	0
Source	15	0.605	0.151	0
Source	16	0.787	0.079	0
Source	17	0.331	0.141	0.019
Justification	18	0.654	0.095	0
Justification	19	0.727	0.098	0
Justification	20	0.597	0.084	0
Justification	21	0.78	0.061	0
Justification	22	0.213	0.052	0
Justification	23	0.516	0.121	0
Justification	24	0.54	0.1	0

Conditions and Design

Experiment 3 used materials from Experiments 1 and 2, as described in Chapters 3 and 4. The design and procedure employed in Experiment 3 was also like the ones used in Experiments 1 and 2. The experiment used a between-subjects design. Participants

were randomly assigned to one of four groups, which served as the between-subjects factor.

Intervention Texts

The intervention testing materials consisted of two informational texts, one that has been constructed for epistemic sensitization (experimental condition), and one that has not (control condition) described in Chapter 3.

Multiple Texts

The participants in three of the four groups read seven separate texts about different aspects of climate change. The rationale for selecting and editing these texts is further described in Chapter 4.

Multiple Text Integration Tasks

The primary measures used in Experiment 2, the Expressive Multiple Text Comprehension Measure (Appendix M) and the Receptive Multiple Text Comprehension Measure (Appendix N), were used in Experiment 3 as one of the conditions.

Data Diagnostics

Planned data diagnostics included peri-data-collection assessment of completion of Parts 1 and 2. It was determined ahead of time that participants who did not fully complete both parts of the study would not be included in analysis, although those that completed Part 1 (defined as having answered all questions across all pages in the survey) would be compensated for their time. Throughout the course of data collection, eight participants did not complete both parts of the study and were removed from the final sample for analysis.

For this study, no data imputation was performed. Participants were strongly encouraged to complete every item, and any participants who did not complete an item were excluded from analysis. Any outliers in the data would be identified by standardized residuals greater than ±3 standard deviations. Analyses will be conducted including and excluding outliers, in order to examine the effects of outliers on findings and understand if any outliers are changing the nature of the findings. Data transformations were only undertaken to meet assumptions for statistical inference, where appropriate. For analyses herein, assumptions included normal distribution and homoscedasticity, in addition to a lack of outliers.

Analytic Strategy

The strategy for inferential statistics in this experiment was to compare four groups with three levels of variation in independent variables, using experimental design through blind randomization of intervention assignment. The planned and leveraged analysis was a one-way ANCOVA; a 3-way fractional factorial design was also considered, given there were three levels of intervention, each with the option of intervention or control (intervention text or control text, multiple texts or no multiple texts, multiple text integration tasks or no multiple text integration tasks, leading three levels of conditions with two conditions each, or 2x2x2=8). However, given the research design in which order of display matters, as well as the research goal of comparing differences across groups rather than examining interaction effects, I proceeded with a one-way ANCOVA.

Because four group means were compared for the primary hypothesis, as well as for the secondary hypothesis, there was a need to plan for protection of experimentwise error across all hypotheses in the ANCOVA. This was done through planned post hoc tests if the primary hypothesis ended up being supported.

Results

In this section, I begin by presenting analysis undertaken to compare the four groups with respect to topic-specific epistemic beliefs. Next, I describe analysis on the effects of experimental conditions on participants' beliefs about epistemic cognition long-term. A final section discusses the results in the context of each research question.

Primary Analysis

The primary analysis focused on addressing whether the multiple texts and multiple text integration tasks changed certainty beliefs about climate change, following an epistemic certainty intervention. The questions driving primary analysis was "Conversely, can engaging in multiple-text integration tasks lead to significant differences in epistemic certainty about climate science?". An ANCOVA was selected to determine if the introduction of multiple texts and multiple text integration measures in Experiment 2 led to additional changes in epistemic beliefs, as seen in the results of Experiment 1.

Prior to conducting the ANCOVA, the data were examined for violations to assumptions. Results of evaluation of the assumptions were satisfactory, as follows. There was a linear relationship between climate change knowledge and topic-specific epistemic belief questionnaire for each intervention type, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes as the interaction term was not

statistically significant, $F(3,154) = .335$, $p = .800$. Standardized residuals for the interventions were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). Standardized residuals for the overall model were also normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). There was homoscedasticity, as assessed by visual inspection of the standardized residuals plotted against the predicted values. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p = .586$). There are no outliers in the data, as assessed by no cases with standardized residuals greater than ±3 standard deviations.

An ANCOVA was used to determine if the introduction of multiple texts and multiple text integration measures in Experiment 2 led to additional changes in certainty beliefs specifically, as seen in the results of Experiment 1. After adjustment for climate-change knowledge, there wasn't a statistically significant difference in topic-specific epistemic beliefs between the interventions, $F(3, 157) = 1.574$, $p = .198$, partial $\eta^2 = .029$. Because the omnibus test was not statistically significant, no post hoc tests were conducted. Post-intervention TSEBQ certainty scores were not statistically significantly different across pairwise controls.

Table 11

Adjusted mean scores for certainty belief scores

			95% Confidence Interval	
Group	Mean	Std. Error	Lower Bound	Upper Bound
A	5.462	0.337	4.796	6.128
B	5.606	0.322	4.969	6.242
C	4.700	0.326	4.055	5.345
D	5.450	0.330	4.798	6.102

Secondary Analysis

Secondary analysis depended upon statistically significant differences in primary analysis. Given primary analysis results were not statistically significantly different across groups, secondary analysis was not pursued.

Exploratory analysis

Given the adjusted mean for Group C was lower than the other three groups, even if not significantly so based on the ANCOVA, three contrast analyses were run to explore this descriptive difference. The new alpha level for these analyses was p = 0.167.

The first was to compare the difference between Group C and Groups A, B, and D combined. The purpose of this analysis was to see if engaging in the multiple text integration tasks led to differences. There was no statistically significant difference in TSEBQ certainty belief scores from the intervention text only group to the other groups, a mean difference of 4.9, 95% CI [-0.224, 10.002], p = .032.

The second was to compare the difference between Groups A and B combined against Group C. This would more precisely target differences in engaging in the multiple text integration tasks, everything else held constant. There was no statistically significant difference in TSEBQ certainty belief scores from the intervention text only group to the other groups, a mean difference of 5.0, 95% CI [-0.429, 10.445], p = .039.

The third was to compare the difference between Groups A and D combined against Group C. This would more precisely target differences in engaging in both multiple text integration tasks compared to know multiple text integration tasks. There was no statistically significant difference in TSEBQ certainty belief scores from the intervention text only group to the other groups, a mean difference of 4.6, 95% CI [-0.833, 10.065], p = .057.

Discussion

Support of Original Hypotheses

To examine the research question, “Can engaging in multiple-text integration tasks lead to significant differences in epistemic certainty about climate science?”, an ANCOVA was performed to analyze differences across four groups and three conditions, using the prior knowledge measure as a covariate. The purpose of this analysis was to look at differences between groups to investigate whether there was statistically significant difference between the experimental condition and the control condition. Using adjusted means, the epistemic belief scores were not significantly different across the four conditions. Results of the ANCOVA and descriptive statistics indicate that participants in the experimental condition had higher topic-specific certainty after reading their assigned text than those participants in the control group, supporting the hypothesis that the experimental text may be effective in promoting more certain epistemic beliefs around anthropogenic climate change. These results enabled subsequent analyses determining if there was any support for persistence in changes to epistemic beliefs after delay and exploring if these changes were to just the one dimension of epistemic certainty, or across multiple dimensions of epistemic beliefs. Given this, the secondary research questions

were not addressed, as this was contingent upon statistically significant results in the primary analysis.

To further explore mean differences seen as a result of primary analyses, contrast analyses were performed to analyze differences between pairs of groups, using the prior knowledge measure as a covariate. Using adjusted means, the epistemic belief scores for the dimension of certainty were not significantly different for any of these analyses.

Interpretation

The purpose of Experiment 3 was to try and identify the effects of multiple text comprehension and integration tasks on certainty beliefs with regards to climate science. The intervention did not yield statistically significant differences; moreover, the two conditions that included all multiple text comprehension and integration tasks (reading the texts and completing both expressive and receptive tasks) and differed only in whether the intervention or control text was assigned did not have statistically significant differences, indicating that the effects of the intervention, if any, were minimized or diminished through engaging in other tasks. Future research should consider testing rigor of interventions and persistence of effects across varying interventions.

The absence of significant epistemic belief changes following multiple text engagement suggests that mere exposure to conflicting information, even with integration tasks, may be insufficient to drive belief revision-a finding with critical implications for cognitive and learning science. Cognitive load theory offers one explanation: synthesizing divergent texts likely strained working memory, diverting executive resources from deeper epistemic reflection. Although results of contrast analyses were not statistically significant, mean scores did differ for the group with the least amount of cognitive load. This aligns with evidence that intertextual integration demands (e.g., inhibiting conflicting claims, coordinating perspectives) can overwhelm learners without structured scaffolds. Furthermore, Bendixen and Rule's (2004) model clarifies why initial intervention effects (Experiment 1) did not amplify: epistemic volition and resolution strategies may not have been sufficiently activated during text integration, as learners defaulted to surface-level processing rather than strategic doubt resolution.

These results underscore the need for epistemically aligned task design. For instance, pairing multiple texts with metacognitive prompts (e.g., "How does this source challenge your current understanding?") could enhance volition and strategy use, per the Cognitive Affective Engagement Model (List & Alexander, 2017). Additionally, individual

differences in epistemic maturity likely mediated outcomes: learners with less sophisticated beliefs may require incremental scaffolding (e.g., source reliability cues, argument mapping) to reconcile textual conflicts. This highlights a tension between constructivist learning ideals and cognitive constraints, suggesting that epistemic growth in complex domains like climate science requires not just exposure to evidence, but deliberate practice in evaluating and integrating knowledge claims within capacity limits.

Generalizability

While this study was intentionally developed to maximize generalizability through controlling all variables possible and using experimental design, there are still elements that impact external validity. The contextual issues that impact generalizability of this study apply to all three studies and are therefore discussed further in Chapter 6.

Implications

A thorough discussion of implications is provided in Chapter 6.

Chapter 6:
Discussion

Understanding how people think about scientific knowledge—especially in complex, controversial domains like climate change—has become increasingly important in today's information-rich world. Prior research has shown that it is not just conceptual knowledge on a topic like climate change that influences behavior, but that epistemic beliefs play a critical role in translating that knowledge to behavior (e.g., Ding et al., 2011; Engels et al., 2013). And that in order to develop a population that engages in pro-environment behaviors, we need to go beyond climate literacy to understand other factors that impact behavior (Heimlich & and Ardoin, 2008). This is especially critical because unmitigated climate change has dire consequences on more than just the environment, and the distribution of such consequences disproportionately affects certain populations including women, lower income populations, and BIPOC (Black, Indigenous, and People of Color) populations (Parsons et al., 2024). Already, we see effects such as increasing gender violence (*Colliding Crises: How the Climate Crisis Fuels Gender-Based Violence*, n.d.) and decreasing food production (Mirón et al., 2023). Given this, we argue for the critical need to continue to study any identifiable factors that influence climate change-related behaviors—such as epistemic beliefs—and how to intervene toward more climate-friendly behaviors.

As a small step toward addressing this need, the present dissertation investigated whether a brief, text-based intervention can lead to differences in epistemic beliefs on climate change, and whether any differences due to the intervention could transfer to how people comprehend and integrate information from multiple texts as they navigate a complex world full of various sources of information on climate change. To address these questions, this research program was organized into three sequential experiments. The first study examined whether reading a short, "epistemic sensitization" text-explicitly designed to promote adaptive beliefs about the certainty of climate science-can shift readers' certainty beliefs compared to a control text. The second study extended this work by testing whether any changes in epistemic beliefs, induced by the intervention, subsequently enhance participants' ability to comprehend and integrate information from multiple, and sometimes conflicting, climate science texts. Finally, the third study explored the potential for a bidirectional relationship by investigating whether engaging in multiple

text comprehension and integration tasks can, in turn, further influence participants' epistemic beliefs about climate change.

By systematically isolating and then combining the effects of short textual interventions and multiple text comprehension tasks, this dissertation aimed to clarify the mechanisms by which epistemic beliefs can be changed and how these changes might impact, and be impacted by, complex literacy tasks. This multi-study approach not only tested theoretical claims about the dynamic relationship between epistemic cognition and reading multiple and conflicting texts but also has practical implications for science education and public understanding of climate change.

Results and Implications

While the main goal of this series of studies was to examine the effects of a short textual intervention on epistemic change, the study also involved examining the effects of multiple text reading and integration tasks on epistemic change.

Support of Original Hypotheses

Implications for Short Textual Interventions for Epistemic Beliefs

Study 1 provides compelling evidence that epistemic beliefs about the certainty of climate science can be meaningfully influenced through a brief, targeted text intervention. Participants who read a short refutation text—designed to emphasize the evolving and uncertain nature of scientific knowledge—came away with more sophisticated beliefs, recognizing that knowledge in climate science is not fixed but subject to revision as new evidence emerges. This shift was evident shortly after the intervention and persisted one week later, suggesting that even brief educational messages can have a lasting impact on how individuals think about the nature of scientific knowledge.

Importantly, the intervention's effects were specific and focused. The observed changes were concentrated in participants' beliefs about certainty, with no comparable changes in related dimensions such as simplicity, source, or justification. This precision indicates that epistemic dimensions can be selectively influenced, offering empirical support for the idea that epistemic cognition is multifaceted and amenable to targeted intervention. The results also extend previous applications of refutation texts—traditionally used to address conceptual misconceptions—into the realm of epistemic belief change, broadening the methodological tools available for research in this area.

The sustained nature of these changes raises important questions for theory and practice alike. It challenges the assumption that epistemic beliefs are deeply entrenched

and difficult to shift, and instead highlights their potential malleability, even in response to short-term interventions. Moreover, it suggests that helping individuals recognize the tentativeness of scientific knowledge may be a necessary step in fostering deeper cognitive engagement with complex, controversial issues like climate change. In turn, such beliefs may play a foundational role in motivating evidence-based reasoning and sustainable behaviors—particularly in contexts where scientific uncertainty is often misinterpreted as grounds for skepticism or inaction.

Finally, this study offers a methodological caution relevant for future epistemic cognition research: preliminary findings revealed that pretest measures may themselves influence participants' beliefs, raising concerns about measurement effects. This highlights the need for continued refinement of research designs that minimize unintended priming and more accurately capture authentic belief change. Taken together, the findings from Study 1 establish a foundation for future investigations into the link between epistemic beliefs and multiple text comprehension, and support the value of brief, theory-informed interventions as practical tools for improving science literacy in an age of information overload.

Implications for Short Textual Interventions on Multiple Document Comprehension

In contrast to the findings from Study 1, the results of Study 2 suggest that changes in epistemic beliefs—while possible—may not be sufficient on their own to enhance complex cognitive tasks like multiple text integration. Participants who received the epistemic sensitization text did not show meaningful differences in how they integrated information across texts, either in terms of identifying key relationships (receptive integration) or constructing coherent written arguments (expressive integration), when compared to those in the control condition.

These results point to an important boundary condition in the relationship between epistemic cognition and text-based reasoning. While individuals may adopt a more evaluativist stance toward knowledge following a targeted intervention, this shift does not automatically translate into improved performance when navigating and synthesizing multiple, potentially conflicting information sources. The challenge of multiple text integration likely demands not just belief change, but support in applying those beliefs—especially in cognitively demanding contexts that require weighing, coordinating, and reconciling diverse perspectives.

This has important implications for educational design. Brief epistemic interventions, like the one used here, may serve as a necessary starting point, but they are unlikely to be sufficient in isolation. Learners may need more explicit support in connecting their epistemic beliefs to strategies for evaluating and integrating information—such as guided controls, structured reflection prompts, or practice identifying source perspectives. These findings also highlight the value of aligning interventions with task demands and considering individual differences in epistemic development. Some participants may have internalized the intervention message but lacked the metacognitive or strategic resources to enact those beliefs during the integration tasks.

Overall, Study 2 contributes to a more nuanced understanding of what it takes to foster epistemically informed reasoning in real-world contexts. Promoting sophisticated beliefs about knowledge is an important step, but the pathway from belief to behavior is not automatic. Supporting learners in bridging that gap—particularly when reasoning across multiple texts—will likely require a combination of belief-shaping, task-specific scaffolding, and extended engagement. Future work should continue exploring how to design interventions that not only shift how learners think about knowledge but also equip them to act on those beliefs when it matters most.

Implications for Multiple-Text Comprehension and Integration for Epistemic Beliefs

Study 3 sought to explore whether participating in multiple text comprehension and integration tasks—such as reading conflicting texts and constructing integrative responses—could shift epistemic beliefs about the certainty of climate science. However, the results did not support this hypothesis. Participants' beliefs about the nature of scientific knowledge remained largely unchanged, regardless of whether they had received an epistemic intervention or not. Even when participants were asked to engage deeply with texts that presented divergent viewpoints, no meaningful shifts in their epistemic beliefs were observed.

These findings suggest that merely encountering conflicting information and engaging in integration tasks is not sufficient to prompt epistemic change. The process of multiple text comprehension, while cognitively demanding, may not inherently lead learners to reflect on the nature of knowledge itself—especially in the absence of explicit support or scaffolding. One possible explanation is that the complexity of the task taxed participants' cognitive resources, leaving little bandwidth for the kind of reflective processing that epistemic change requires. Without guidance to direct attention toward

the epistemic dimensions of the task—such as evaluating source reliability or considering the evolving nature of claims—participants may have focused primarily on surface-level comprehension rather than engaging in deeper epistemic reasoning.

This interpretation aligns with existing theoretical models that emphasize the role of volition, metacognition, and strategy use in epistemic development. From this perspective, even thoughtfully designed tasks may fall short if they do not activate learners' motivation to reflect on their own beliefs or provide cues that make epistemic evaluation visible and actionable. The results also underscore the importance of individual differences. Learners at earlier stages of epistemic development may not spontaneously engage in evaluative thinking when reading conflicting texts unless explicitly prompted to do so.

Together, these findings highlight the need for more intentional and scaffolded instructional approaches when the goal is to promote epistemic growth through multiple text engagement. Brief exposure to conflicting information is unlikely to shift beliefs unless paired with cognitively manageable strategies that invite learners to question, compare, and reflect on knowledge claims. Embedding prompts that encourage evaluation (e.g., "How does this source compare to others?" or "What makes this claim more or less credible?") may help bridge the gap between task engagement and epistemic insight. Study 3 thus adds to a growing body of work suggesting that belief change—particularly in complex scientific domains—requires both conceptual support and structured opportunities to apply epistemic thinking during knowledge construction.

Overall Implications

Taken together, the three studies presented in this dissertation offer a nuanced view of the promise and limits of brief interventions for supporting epistemic change in the context of climate science. Study 1 demonstrated that even a single, targeted reading experience can meaningfully shift beliefs about the certainty of scientific knowledge, with effects persisting for at least one week. This finding suggests that epistemic beliefs are more malleable than traditionally assumed, and that low-cost, text-based interventions can serve as effective tools for initiating conceptual reflection—particularly when they are precisely aligned with a targeted epistemic dimension, such as certainty.

However, Studies 2 and 3 revealed important boundary conditions to this effect. In Study 2, participants who received the intervention text did not show improved performance on receptive or expressive multiple text integration tasks. In Study 3,

engaging in those integration tasks did not in itself lead to measurable changes in epistemic beliefs. These findings suggest that belief change, while possible, does not necessarily translate into more sophisticated information integration—or vice versa. The cognitive demands of integrating conflicting information may overwhelm the kinds of reflective processes that epistemic change requires, especially in the absence of explicit support. Learners may need more than just exposure to complex information; they may require structured opportunities to apply evaluativist thinking, alongside scaffolding that makes epistemic strategies visible and actionable.

These results contribute to a growing body of evidence indicating that fostering epistemic growth in real-world settings is a multifaceted challenge. They underscore the importance of carefully designing tasks that align with epistemic goals, and of recognizing the role of individual differences—such as prior knowledge, motivation, and developmental readiness—in shaping outcomes. The lack of significant effects in Studies 2 and 3 also highlights the need for further methodological refinement. Future research should explore alternative ways of measuring integration, consider longer or more immersive interventions, and test how various instructional supports might help learners connect their epistemic beliefs to the demands of reasoning across texts.

Importantly, these findings highlight the value of publishing null results. Understanding when and why interventions fail is just as critical as knowing when they succeed—especially for a field as complex and consequential as epistemic cognition. This work builds a more complete picture of what is required to help individuals reason thoughtfully about contested issues like climate change. Future research should continue testing interventions of varying length, intensity, and structure to determine what conditions reliably produce lasting change. Investigating potential moderators such as epistemic beliefs at baseline, topic relevance, or identity-based motivations may further clarify how best to support learners in becoming both critical consumers of information and reflective thinkers about the nature of knowledge itself. the conditions under which epistemic interventions may be most effective.

Generalizability

The generalizability of findings from these three experiments is shaped by the study's design decisions, participant sample, domain-specific focus, and measurement tools. While every effort was made to support external validity, several limitations should be considered when interpreting the broader applicability of the results.

Sample Characteristics and Recruitment

Participants were recruited exclusively through Prolific, a vetted online crowdsourcing platform. Although this platform offers high data quality and demographic diversity, it may introduce self-selection bias. Individuals who opt into compensated online studies may differ from the general population in terms of educational background, digital literacy, or familiarity with climate-related discourse. Eligibility criteria further limited the sample to U.S.-based, English-fluent adults with consistent internet access, which may reduce applicability to broader or offline populations. Future research should aim to replicate findings with larger and more varied samples to better assess intervention effects across demographic groups.

Ecological Validity and Experimental Context

The studies were conducted in controlled, online settings designed to isolate the effects of brief textual interventions. While this supports internal validity, it also limits ecological validity. Reading and reasoning about multiple texts in experimental tasks differs from doing so in everyday contexts, where learners encounter information in less structured, more socially mediated environments. The extent to which findings generalize to classroom instruction, informal learning, or digital media engagement remains an open question.

Topic Specificity and Domain Sensitivity

Epistemic beliefs are domain-sensitive, and this research focused specifically on beliefs about the certainty of knowledge in the context of climate change—a socially and politically charged socioscientific issue. While this makes the intervention relevant to real-world challenges, it also constrains generalizability. Adaptive epistemic stances in other domains—particularly more technical, emotionally neutral, or less controversial ones—may operate differently. The intervention's effectiveness may also vary depending on whether a topic evokes identity-relevant values or is treated as abstract knowledge. Future work should explore how epistemic interventions function across varied disciplines and epistemic conditions.

Design Constraints and Pretest Considerations

Resource limitations shaped key aspects of study design, including sample size and the decision to remove a pretest measure. The original plan for a within-subjects design was revised after pilot testing revealed that pretesting epistemic beliefs sensitized participants to the intervention, undermining ecological validity. While removing the pretest

preserved the integrity of the intervention effect, it introduced challenges in detecting within-person change and accounting for baseline differences in epistemic beliefs. Random assignment helped mitigate this, but the ability to assess individual trajectories of change was lost. In the future, researchers may consider alternate approaches—such as delayed pretests or mixed methods—to balance measurement sensitivity with external validity.

Measurement Limitations

This study relied on established self-report measures of epistemic cognition and custom-designed tasks to assess multiple text integration. While these tools were validated and carefully scored, they may not fully capture the nuanced, context-dependent nature of epistemic reasoning or integration strategies. As prior research has noted, standard epistemic measures often oversimplify belief dimensions, and multiple text tasks may miss subtle aspects of source evaluation, synthesis, or critical reflection. Despite efforts to triangulate through expressive and receptive tasks, both domains would benefit from continued development of process-oriented and multimodal assessments that can more accurately reflect real-world reasoning.

These limitations, while inherent to the design and scope of the present research, also point to valuable directions for future inquiry. The following section outlines specific recommendations for building on this work—both to deepen our understanding of epistemic cognition in context and to refine interventions that promote integration of knowledge across complex, conflicting texts.

Future Research

Some of the future research that should be considered has been mentioned in the context of limitations—that is, how addressing limitations in future research could add evidence toward scientifically supported theories on the extent to which short textual interventions can influence epistemic change, if at all, and the role multiple text reading and integration may play in such changes.

Psychometric analyses frequently uncover issues with the reliability and validity of these instruments, including low internal consistency and factor structures that do not always align with theoretical models, which aligns with the factor analysis completed for Experiment 1. Qualitative approaches, such as interviews and think-aloud protocols, have shown that individuals' epistemic beliefs are often more sophisticated and context-

sensitive than what is captured by traditional surveys, highlighting the need for more nuanced and contextually grounded assessment methods.

While Bendixen and Rule's model (2004) emphasizes doubt, volition, and resolution as drivers of epistemic change, this process is likely moderated by individual and contextual variables. For instance, pre-existing climate change beliefs may shape how doubt is triggered: individuals with strong prior convictions (e.g., climate skeptics) may resist refutation texts due to motivated reasoning, whereas those with neutral or uncertain views may be more receptive. Similarly, political affiliation could influence epistemological volition, as partisan identity often filters engagement with evidence-a dynamic well-documented in climate communication research. For example, conservatives exposed to refutation texts may dismiss contradictions as "liberal bias," while progressives might uncritically accept climate claims aligned with their ideology. These patterns suggest that the intervention's efficacy is not uniform but mediated by sociocognitive factors. The quantitative data from this study-particularly interactions between political identity, pretest beliefs, and posttest epistemic scores-could be reanalyzed to test these hypotheses, identifying boundary conditions for belief revision. Furthermore, the measures used in Experiment 2 invite a qualitative follow-up: a qualitative grounded theory approach to analyzing expressive task responses could reveal how participants reconciled multiple (and sometimes conflicting) texts, capturing nuances like trust in sources, emotional responses, or adherence to beliefs or knowledge not expressed in either the experimental/control text or multiple texts. Such work would deepen our understanding of the potential effects of epistemic sensitization interventions in the face of other information on climate change.

Extensive research demonstrates that epistemic beliefs are not only general dispositions but also operate at domain- and topic-specific levels, with beliefs about knowledge and knowing often varying substantially across different subjects and even within subtopics of a domain. For example, an individual's epistemic beliefs about climate change may differ from their beliefs about other scientific topics or entirely different domains such as history or mathematics. Empirical studies have shown that topic-specific epistemic beliefs are often stronger predictors of learning processes and outcomes than general or even domain-specific beliefs, as they are more closely tied to the concrete content and learning activities at hand. Consequently, while this intervention showed some effectiveness in shifting participants' epistemic beliefs about climate change in the short-

term, these results may not necessarily extend to other topics or domains given similar interventions. Future research should therefore examine whether similar interventions can influence epistemic beliefs across a range of topics, and whether topic-specific effects observed here are replicable in other content areas.

More broadly, there is an unending expanse of future research needed on how education can adequately support individuals in gaining needed cognitive abilities, including epistemic cognition, that enables them to engage with new information while reducing risk of susceptibility to misinformation. Current inoculation approaches show mixed results; while some studies have found that explaining misleading techniques can neutralize polarizing effects of misinformation (Cook et al., 2017), subsequent testing of inoculation strategies showed limited protective effects (Spampatti et al., 2024). Future research should investigate why some inoculation approaches are more effective than others and how to design strategies that work across different audiences and contexts.

Conclusion

People's epistemic beliefs-their views about the nature and reliability of knowledge-can indeed be influenced by targeted, short-term interventions, as demonstrated in Experiment 1. The findings align with research demonstrating that refutation texts-which explicitly challenge misconceptions and provide evidence-based alternatives-can induce epistemological doubt, a critical mechanism for belief revision. This process is theorized in Bendixen and Rule's Process Model of Epistemological Change (2004), where doubt triggers reflection and social interaction to resolve cognitive dissonance.

However, these changes are often fragile and can be undermined by persistent exposure to different presentations of information (including conflicting information) as supported by the lack of significant differences seen in Experiments 2 and 3. Sustained change may require more than isolated interventions. While epistemic sensitization texts taking a refutation approach appear to enhance short-term differences in epistemic certainty about climate change, their efficacy may depend on other psychological components theorized to influence epistemic cognition, including alignment with recipients' epistemic volition (willingness to revise beliefs) and more concrete resolution strategies (e.g., prompted deep reflection, social interaction) as proposed by Bendixen and Rule.

This means that while brief interventions have value, they are not a panacea; rather, they must be part of a broader, sustained effort to foster critical thinking, resilience to

misinformation, and a deeper engagement with scientific evidence. The findings presented here highlight both the potential and the limitations of such interventions, underscoring the need for multi-faceted approaches that address not only individual beliefs but also the complex information environments shaping public understanding of issues like climate change.

The research presented herein was designed in 2020; at the time, public perception of climate change as a major threat seemed to be continuing on a steadily increasing trajectory, and there was some thought as to the necessity of such research (Kennedy, 2023). If more and more people were viewing climate change as a major threat, perhaps the “wicked problem” was not as wicked as once thought (Rittel & Webber, 1973). Since then, however, the same longitudinal study from Pew Research has detected decreases across the partisan divide, underscoring the continued significance of this problem. And even as new tactics such as doomism are being taken by bad actors interested in undermining climate change action (Mann, 2020), research continues to show that sowing doubt in anthropogenic climate change continues to be strongly present in climate change communications (Boussalis & Coan, 2016). Given this, the need for research that addresses not only climate skepticism but also the proliferation of sophisticated misinformation is more pressing than ever. As recent studies and media analyses have shown, false narratives and disinformation-now amplified by new technologies and shifting tactics-continue to undermine public understanding and stall meaningful climate action. The findings of this dissertation underscore the potential and the limits of brief, targeted interventions to shift epistemic beliefs about climate science. Yet, they also highlight that lasting change will require sustained, adaptive strategies that address both the psychological and informational landscape in which people encounter climate issues. As the climate crisis accelerates and the information environment grows more complex, the challenge for researchers, educators, and journalists is not only to correct misconceptions, but to provide necessary tools for individuals to identify and disregard misinformation and to foster a sense of agency and hope that can motivate collective action. The work presented here is a step toward that goal, and it is my hope that future research will continue to refine, expand, and implement evidence-based approaches to strengthen public engagement and resilience against the forces of doubt and despair.

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Appendix A :

Consent Form

Form HRP-587: INFORMATION SHEET FOR RESEARCH

Information Processing Study

You are invited to be in a research study of how individuals process information provided in different texts. You were selected as a possible participant because you are registered as a research participant with Prolific. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by: Christina Zdawczyk and Keisha Varma, Department of Educational Psychology (University of Minnesota)

Procedures:

If you agree to be in this study, we would ask you to do the following things:

You will be asked to complete a survey which will require you to answer multiple choice questions, read some text, and then answer several more multiple-choice questions. You will also be asked to participate in a short follow-up survey one week from today.

Confidentiality:

The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records.

Voluntary Nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

Contacts and Questions:

The researcher(s) conducting this study is (are): Christina Zdawczyk and Keisha Varma. You may ask any questions you have now. If you have questions later, you are encouraged to contact them at zdawc001@umn.edu or keisha@umn.edu, (612-626-899).

This research has been reviewed and approved by an IRB within the Human Research Protections Program (HRPP). To share feedback privately with the HRPP about your research experience, call the Research Participants' Advocate Line at 612-625-1650 (Toll Free: 1-888-224-8636) or go to z.umn.edu/participants. You are encouraged to contact the HRPP if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research participant.
- You want to get information or provide input about this research.

You will be given a copy of this information to keep for your records.

Appendix B :

Topic Specific Epistemic Belief Questionnaire (TSEBQ)

Please answer the following 24 questions. If you strongly agree with a statement, select 10; if you strongly disagree, select 1. If you more or less agree with a statement, select the number between 10 and 1 that best expresses your belief.

Certainty

1. What is considered to be certain knowledge about climate today, may be considered to be false tomorrow.
2. Certain knowledge about climate is rare.
3. The results of climate research are preliminary.
4. Theories about climate can be disproved at any time.
5. The knowledge about issues concerning climate is constantly changing.
6. Problems within climate research do not have any clear and unambiguous solution.

Simplicity (Reverse Coded)

7. With respect to knowledge about climate, there are seldom connections among different issues.
8. Within climate research, accurate knowledge about details is the most important.
9. Within climate research, various theories about the same phenomenon will make things unnecessary complicated.
10. Knowledge about climate is primarily characterized by a large amount of detailed information.
11. The knowledge about climate problems is indisputable.
12. There is really no method I can use to decide whether claims in texts about issues concerning climate can be trusted.

Sources (Reverse Coded)

13. I often feel that I just have to accept that what I read about climate problems can be trusted.
14. When I read about issues concerning climate, the author's opinion is more important than mine.
15. With respect to climate problems, I feel I am on safe ground if I only find an expert statement.
16. When I read about climate problems, I only stick to what the text expresses.
17. My personal judgments about climate problems have little value compared to what I can learn about them from books and articles.

Justification

18. To check whether what I read about climate problems is reliable, I try to evaluate it in relation to other things I have learned about the topic.
19. When I read about issues related to climate, I try to form my own understanding of the content.
20. To gain real insight into issues related to climate, one has to form one's own personal opinion of what one reads.
21. When I read about issues concerning climate, I evaluate whether the content seems logical.

22. To be able to trust knowledge claims in texts about issues concerning climate, one has to check various knowledge sources.
23. Within climate research, there are connections among many topics.
24. I understand issues related to climate better when I think through them myself, and not only read about them.

Appendix C :

Climate Change Concept Inventory

You will now be asked to answer 21 questions. Please read each of the following questions carefully. Choose the answer that most closely aligns with your understanding of climate science.

1. Which is the most common form of radiation given off by the Sun?
    - **A. The Sun mostly gives off visible radiation.**
    - B. The Sun mostly gives off infrared radiation.
    - C. The Sun mostly gives off ultraviolet radiation.
    - D. The Sun does not give off radiation.
    - E. I do not know.

2. What do greenhouse gases do as part of the greenhouse effect?
    - **A. Greenhouse gases absorb energy emitted by Earth.**
    - B. Greenhouse gases reflect energy emitted by Earth.
    - C. Greenhouse gases reflect energy reflected by Earth.
    - D. Greenhouse gases absorb energy reflected by Earth.
    - E. I do not know.

3. Averaged over long time periods, how does the amount of energy arriving from space compare to the amount of energy leaving Earth?
    - A. The amount of energy arriving from space is greater than the amount of energy leaving Earth.
    - B. The amount of energy arriving from space is less than the amount of energy leaving Earth.
    - **C. The amount of energy arriving from space is roughly equal to the amount of energy leaving Earth.**
    - D. I do not know.

4. Where will a photon emitted by a greenhouse gas molecule most likely go?
    - A. In an upward direction relative to Earth’s surface.
    - B. In a downward direction relative to Earth's surface.
    - **C. In a random direction relative to Earth’s surface.**
    - D. I do not know.

5. What information do ice cores from glaciers contain about Earth? CHOOSE ALL THAT APPLY.
    - **A. Ice cores contain information about Earth's air temperature.**
    - **B. Ice cores contain information about Earth's seasonal precipitation.**
    - **C. Ice cores contain information about Earth's carbon dioxide concentration.**
    - D. Ice cores contain information about Earth's daily weather events.
    - E. I do not know.

6. Which statements about non-greenhouse gases are accurate? CHOOSE ALL THAT APPLY.
    - **A. Non-greenhouse gases do not absorb a lot of energy given off by the Sun.**
    - **B. Non-greenhouse gases do not absorb a lot of energy given off by the Earth.**
    - C. Non-greenhouse gases absorb a lot of energy given off by the Earth.
    - D. Non-greenhouse gases absorb a lot of energy given off by the Sun.
    - E. I do not know.

7. How much incoming sunlight do greenhouse gases absorb?
    - **E. Greenhouse gases absorb almost no incoming sunlight.**
    - F. Greenhouse gases absorb about half of the incoming sunlight.
    - G. Greenhouse gases absorb most incoming sunlight.
    - H. I do not know.

8. Which is the best definition of a positive feedback loop in the climate system?
    - A. A change in the climate system leads to a response that benefits climate change.
    - B. A change in the climate system leads to a response that slows down climate change.
    - **C. A change in the climate system leads to a response that speeds up climate change.**
    - D. A change in the climate system leads to a response that harms climate change.
    - E. I do not know.

9. Which of the following is the best definition of a greenhouse gas?
    - A. An atmospheric gas that is produced as plants grow.
    - **B. An atmospheric gas that absorbs infrared radiation.**
    - C. An atmospheric gas that produces acid rain.
    - D. An atmospheric gas that absorbs ultraviolet radiation.
    - E. I do not know.

10. Which is the most common form of radiation given off by Earth's surface?
    - A. The Earth's surface mostly gives off visible radiation.
    - **B. The Earth's surface mostly gives off infrared radiation.**
    - C. The Earth's surface mostly gives off ultraviolet radiation.
    - D. Earth's surface does not give off radiation.
    - E. I do not know.

11. Which of the following statements about air temperature change over the past million years is most accurate?
    A. Air temperature change over the past million years is slightly due to natural processes and mostly due to human activities.
    B. Air temperature change over the past million years is mostly due to natural processes and slightly due to human activities.
    C. Air temperature change over the past million years is about equally due to natural processes and human activities.
    D. Air temperature change over the past million years has not occurred whether due to natural processes or human activities.
    E. I do not know.

12. Which of the following could cause the Earth's surface temperature to change? CHOOSE ALL THAT APPLY.
    A. Changes in the tilt of the Earth's axis.
    B. Changes in the reflectivity of the Earth's surface.
    C. Changes in methane concentrations in the atmosphere.
    D. Changes in carbon dioxide concentrations in the atmosphere.
    E. I do not know.

13. Which of the following will occur if the amount of ice floating in the ocean decreases?
    A. More sunlight will be reflected back into space and Earth's temperature will decrease.
    B. Less sunlight will be reflected back into space and Earth's temperature will increase.
    C. More sunlight will be reflected back into space and Earth's temperature will increase.
    D. Less sunlight will be reflected back into space and Earth's temperature will decrease.
    E. I do not know.

14. How does sunlight affect temperature on Earth?
    A. Sunlight warms the air directly, but the air does not warm the land.
    B. Sunlight warms the land directly, but the land does not warm the air.
    C. Sunlight warms the air directly, and the air warms the land.
    D. Sunlight warms the land directly, and the land warms the air.
    E. I do not know.

15. Which of the following statements about global warming over the past 50 years is most accurate?
    A. Global warming over the past 50 years is slightly due to natural processes and mostly due to human activities.
    B. Global warming over the past 50 years is mostly due to natural processes and slightly due to human activities.
    C. Global warming over the past 50 years is about equally due to natural processes and human activities.
    D. Global warming over the past 50 years has not occurred whether due to natural processes or human activities.
    E. I do not know.

16. Which of the following can be caused by climate change? CHOOSE ALL THAT APPLY.
    A. Climate change can cause food shortages.
    B. Climate change can cause changes in temperature.
    C. Climate change can cause water shortages.
    D. Climate change can cause changes in weather.
    E. I do not know.

17. Which of the following contributes to the transfer of thermal energy from place to place around the Earth?
    A. The movement of ocean water but not the movement of air.
    B. The movement of air but not the movement of ocean water.
    C. Both the movement of ocean water and the movement of air.
    D. Neither the movement of ocean water nor the movement of air.
    E. I do not know.

18. Which of the following best describes how plants take in carbon dioxide?
    A. Plants take in carbon dioxide from rain.
    B. Plants take in carbon dioxide from sunlight.
    C. Plants take in carbon dioxide from air.
    D. Plants take in carbon dioxide from soil.
    E. I do not know.

19. Which of the following would most likely occur if the oceans stopped absorbing carbon dioxide?
    A. Carbon dioxide in the atmosphere would remain the same.
    B. Carbon dioxide in the atmosphere would increase.
    C. Carbon dioxide in the atmosphere would decrease.
    D. I do not know.

20. How has the amount of carbon dioxide in the atmosphere changed since the start of the Industrial Revolution 150 years ago?
    A. The amount of carbon dioxide has remained the same.
    B. The amount of carbon dioxide has decreased.
    C. The amount of carbon dioxide has increased.
    D. I do not know.

21. Which is the best description of the differences between climate and weather?
    A. Climate does not change over time, and weather does change over time.
    B. Climate changes over time, and weather does not change over time.
    C. Climate changes over long periods of time, and weather changes over short periods of time.
    D. Climate changes over short periods of time, and weather changes over long periods of time.
    E. I do not know.

Appendix D :

Prolific Demographic Information

Prolific provides the following standard set of demographic data on all approved participants.

- Session ID
- Participant ID
- Submission status
- Custom study T&Cs accepted at (in UTC)
- Started date-time (in UTC)
- Completed date-time (in UTC)
- Time taken
- Age
- Sex
- First language
- Current country of residence
- Nationality
- Country of birth
- Student status
- Employment status
- Reviewed at date-time (in UTC)
- Completion code ('entered code')

Potential participants on the platform are encouraged to answer additional demographic questions, and researchers can use these (in addition to the above) for screening. For all three studies, potential participants were required to match the following screening settings.

- Current Country of Residence = United States
- Fluent Languages = English
- Climate Change = Yes, No, Don’t know

Appendix E :

Collected Demographic Information

1. Please indicate your ethnicity (i.e. peoples' ethnicity describes their feeling of belonging and attachment to a distinct group of a larger population that shares their ancestry, color, language or religion)?
   - African
   - Black/African American
   - Caribbean
   - East Asian
   - Latino/Hispanic
   - Middle Eastern
   - Mixed
   - Native American or Alaskan Native
   - South Asian
   - White/Caucasian
   - Other please feel free to let us know your ethnicity via email
   - White / Sephardic Jew
   - Black/British
   - White Mexican
   - Romani/Traveller
   - South East Asian

2. Which of these is the highest level of education you have completed?
   - No formal qualifications
   - Secondary education e.g. GED/GCSE
   - High school diploma/A-levels
   - Technical/community college
   - Undergraduate degree BA/BSc/other
   - Graduate degree MA/MSc/MPhil/other
   - Doctorate degree PhD/other
   - Don't know / not applicable

3. In general, what is your political affiliation?
   - Democrat
   - Republican
   - Independent
   - Other
   - None

Appendix F :

Experimental Text

Unformatted Text

Epistemic Beliefs about Scientific Topics

Have you ever asked yourself, “How do I know that what I know is true?” Our *epistemic beliefs* help us answer this question. Epistemic beliefs are individuals' beliefs about the nature of knowledge, how knowledge is constructed, and how knowledge can be justified. People can have the same knowledge about a topic—such as “the earth revolves around the sun”—but have very different epistemic beliefs about planetary motion.

For example, we can imagine two people—Taylor and Jordan—who are trying to decide whether they should eat genetically modified foods. Both have limited knowledge about genetically modified organisms (GMOs) and believe they could be dangerous to eat. They also believe that knowledge about GMOs is uncertain and that there are conflicting views as to whether GMOs are safe.

Taylor attributes this uncertainty to her belief that GMOs have only been around for a relatively short time. She doesn’t attempt to resolve the issue by learning more about it, rather resigning herself to the indeterminable state of the question and continuing to avoid GMOs.

Jordan also experiences that the information she has read is uncertain and contradictory. However, rather than accepting this, she tries to resolve the complex issue by cross-checking and integrating information from the different sources on GMOs to build an informed account of the matter. In doing so, Jordan is able to build an understanding that researchers who study GMO effects have developed a consensus that GMOs do not cause cancer, obesity, food allergies, or other health concerns, and are as safe to eat as non-GMOs. She finds that those people who believe GMOs could be dangerous do not conduct research on GMOs and do not have scientific evidence to support this claim. In this way, Jordan’s adaptive epistemic beliefs contributed to her developing a well-grounded understanding of the matter. She now knows that an issue that she believed had a lot of uncertainty actually has a well-supported answer and scientific consensus. As a result of Jordan’s adaptive epistemic beliefs, she can now confidently eat genetically modified foods, which are generally less expensive and taste better.

Similarly, there is a common misconception about the uncertainty of anthropogenic (human-caused or human-influenced) climate change. While it was once true that anthropogenic climate change was considered uncertain, this is no longer the case. In fact, researchers have conducted thousands of studies and formed a body of evidence; these findings support the fact that human activity is causing changes in the earth’s atmosphere and have allowed scientists to create more accurate models for predicting how these changes will continue in the future.

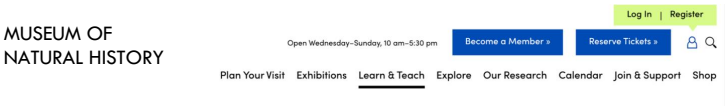
Returning to our previous example, Taylor and Jordan also believe that anthropogenic climate change is uncertain. Taylor’s maladaptive epistemic beliefs lead her to not resolve the issue. She continues to support her belief that climate change is uncertain and therefore decides not to do anything about it. Conversely, Jordan’s adaptive epistemic beliefs lead her to read about the issue and all perspectives, examine the

evidence provided and who is providing it, and help her understand the overwhelming evidence for anthropogenic climate change. This new knowledge she gained through her adaptive epistemic beliefs leads her to vote for policies that mitigate climate change and invest in energy-efficient appliances that reduce energy use while saving her money.

The inherent uncertainty in scientific research, where theories are never proven to be a “final truth” but instead gather a preponderance of supporting evidence through experimentation, makes public understanding of these issues difficult. The tricky part, then, is figuring out what is close enough to the "final truth". For example, public understanding about the health risks of smoking came long after a preponderance of evidence had been produced and health researchers reached a consensus. In the meantime, amidst public uncertainty, policies protecting people from first- and second-hand smoke were not implemented and false uncertainty led people to continue to breath in cigarette smoke, causing cancer, lung disease, strokes, and other health problems in many people.

Likewise, the inherent uncertainty presented with scientific findings on climate change gives a misperception that there is no certainty on anthropogenic climate change, and that climate researchers are still debating the issue. However, this is false. In actuality, evidence does not support both sides of the anthropogenic climate change debate. While not all scientific issues have reached this level of certainty, the health risks of smoking, the safety of consuming GMOs, and anthropogenic climate change are all scientific issues that have a preponderance of support through research conducted by those experts in each field. Overwhelming evidence shows that the climate is changing in ways that will have consequences for humans and other species, and humans can still take concrete steps to mitigate its effects.

Text Presentation



Epistemic Beliefs about Scientific Topics

Have you ever asked yourself, "How do I know that what I know is true?" Our *epistemic beliefs* help us answer this question. Epistemic beliefs are individuals' beliefs about the nature of knowledge, how knowledge is constructed, and how knowledge can be justified. People can have the same knowledge about a topic—such as "the earth revolves around the sun"—but have very different epistemic beliefs about planetary motion.

For example, we can imagine two people—Taylor and Jordan—who are trying to decide whether they should eat genetically modified foods. Both have limited knowledge about genetically modified organisms (GMOs) and believe they could be dangerous to eat. They also believe that knowledge about GMOs is uncertain and that there are conflicting views as to whether GMOs are safe.

Taylor attributes this uncertainty to her belief that GMOs have only been around for a relatively short time. She doesn't attempt to resolve the issue by learning more about it, rather resigning herself to the indeterminable state of the question and continuing to avoid GMOs.

Jordan also experiences that the information she has read is uncertain and contradictory. However, rather than accepting this, she tries to resolve the complex issue by cross-checking and integrating information from the different sources on GMOs to build an informed account of the matter. In doing so, Jordan is able to build an understanding that researchers who study GMO effects have developed a consensus that GMOs do not cause cancer, obesity, food allergies, or other health concerns, and are as safe to eat as non-GMOs. She finds that those people who believe GMOs could be dangerous do not conduct research on GMOs and do not have scientific evidence to support this claim. In this way, Jordan's adaptive epistemic beliefs contributed to her developing a well-grounded understanding of the matter. She now knows that an issue that she believed had a lot of uncertainty actually has a well-supported answer and scientific consensus. As a result of Jordan's adaptive epistemic beliefs, she can now confidently eat genetically modified foods, which are generally less expensive and taste better.

Similarly, there is a common misconception about the uncertainty of anthropogenic (human-caused or human-influenced) climate change. While it was once true that anthropogenic climate change was considered uncertain, this is no longer the case. In fact, researchers have conducted thousands of studies and formed a body of evidence; these findings support the fact that human activity is causing changes in the earth's atmosphere, and have allowed scientists to create more accurate models for predicting how these changes will continue in the future.

Returning to our previous example, Taylor and Jordan also believe that anthropogenic climate change is uncertain. Taylor's maladaptive epistemic beliefs lead her to not resolve the issue. She continues to support her belief that climate change is uncertain, and therefore decides not to do anything about it. Conversely, Jordan's adaptive epistemic beliefs lead her to read about the issue and all perspectives, examine the evidence provided and who is providing it, and help her understand the overwhelming evidence for anthropogenic climate change. This new knowledge she gained through her adaptive epistemic beliefs leads her to vote for policies that mitigate climate change and invest in energy-efficient appliances that reduce energy use while saving her money.

The inherent uncertainty in scientific research, where theories are never proven to be a "final truth" but instead gather a preponderance of supporting evidence through experimentation, makes public understanding of these issues difficult. The tricky part, then, is figuring out what is close enough to the "final truth". For example, public understanding about the health risks of smoking came long after a preponderance of evidence had been produced and health researchers reached a consensus. In the meantime, amidst public uncertainty, policies protecting people from first- and second-hand smoke were not implemented and false uncertainty led people to continue to breath in cigarette smoke, causing cancer, lung disease, strokes, and other health problems in many people.

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Appendix G :

Control Text

Unformatted Text

Bibliometric Research about Scientific Topics

Have you ever wondered, “How do people measure trends in scientific research?” *Bibliometric research* is one way to answer this question. Bibliometrics is the study of scientific publications, answering questions like who is publishing, what topics are they publishing in, and how often these publications are being cited by others. Two sets of publications can be about the same field—such as “astronomy”—but be about different research topics such as asteroids and black holes.

For example, we can imagine two sets of research papers—both on genetically modified organisms (GMOs) —that are trying to understand the health effects of eating genetically modified foods. Both are written by scientists who study GMOs and are testing whether they could be dangerous to eat. They also both use similar research methods.

The first set of papers is on GMOs and diabetes. Bibliometric research shows that from 2000 – 2020 there are a few publications on GMOs and diabetes, and that this research is cited by some other researchers. Further analysis of websites such as Wikipedia and social networking cites such as Twitter show that a few people have read and are discussing this research online.

The second set of papers is on GMOs and cancer. However, bibliometric research shows that from 2000-2020, there were many publications on this topic, and that research is cited extensively by others. An analysis of altmetric data, which tracks where published research is mentioned online, shows that this research has received a lot of attention. Altmetric data shows that many people have downloaded PDFs of these papers. Additional altmetric data on Wikipedia citations, Twitter mentions, science blog discussions, and journal comments shows that this research has been extensively discussed online. Policy citations show that this research has been used in policy decisions regarding the safety of genetically modified foods. In the US, this research has been cited in policy decisions by the FDA to regulate them for food and plant safety. The same can be seen with other governing bodies, such as the European Union. As a result of these analyses, we can now see what research is being used to enable Americans to feel safe about eating certain genetically modified foods, which are generally less expensive and taste better.

Similarly, bibliometric analyses can be done with research on anthropogenic (human-caused or human-influenced) climate change. While it was once true that anthropogenic climate change did not have much research, this is no longer the case. In fact, climate change research accounts for approximately 500,000 research publications from 2000-2020; in 2020, it accounted for 8% of all research done globally, supporting the fact that many people are putting their efforts toward understanding and mitigating anthropogenic climate change.

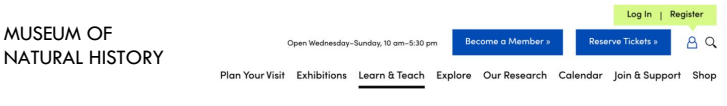
Additionally, two topics within climate change research area that look very different when analyzed bibliometrically are research on climate change adaptation and fossil fuels. The first research area, which is characterized by research on disaster risk reduction, natural hazards, and adaptive capacity, has been growing over the past ten years. However, the second research area, which is characterized by research on the greenhouse effect, has

decreased. This may relate to shifts in research attention from how to prevent climate change to how to mitigate its effects.

The inherent amount of scientific research, due to new articles being published every day at a pace that cannot be analyzed individually, makes these types of analyses important to help research organizations understand trends and make decisions about research funding. The tricky part is understanding how to best analyze the data. For example, US research on climate change adaptation was growing until 2019. However, a look at the pace at which the US research was growing, through calculating the compound annual growth rate, shows that other countries were outpacing the US despite publishing less articles. This allows us to predict that countries such as the UK, Australia, and Germany will surpass US output soon. The US could use these analyses to decide whether or not they want to invest more funding in this research area.

Likewise, analyzing overall research on climate change shows meaningful trends that could inform US policy and funding. Many people may believe that the US has continued to increasingly fund climate change research at a rate similar to other countries. However, this is false. In actuality, US research funding data show that government research funding support toward climate change research has plateaued since 2009. Analyzing the climate change research area by country, we can see that US research output has plateaued since 2011. Given that it takes about two years for research to be published following funding, this shows the dire effects of US funding decisions on US research activities. Bibliometric evidence shows that the US is being outpaced by other countries in climate change research, but US may be able to take concrete steps to pivot through additional funding.

Text Presentation



Bibliometric Research about Scientific Topics

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The inherent amount of scientific research, due to new articles being published every day at a pace that cannot be analyzed individually, makes these types of analyses important to help research organizations understand trends and make decisions about research funding. The tricky part is understanding how to best analyze the data. For example, US research on climate change adaptation was growing until 2019. However, a look at the pace at which the US research was growing, through calculating the compound annual growth rate, shows that other countries were outpacing the US despite publishing less articles. This allows us to predict that countries such as the UK, Australia, and Germany will surpass US output soon. The US could use these analyses to decide whether or not they want to invest more funding in this research area.

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Appendix H :

Experiment 1 Norming Study 1 Procedure

Thank you for taking the time to help test these research materials. This survey should take approximately 8 minutes to complete.

(Participants were randomly selected to read one of three texts: Experimental Text, Control Text 1, or Control Text 2.)

Experimental Text

Please carefully read the following text.

Many of us think that the causes of climate change are uncertain. However, this idea is false. Actually, 97% of climate scientists agree that human behaviors are the primary cause of climate change.

Climate scientists know that humans cause climate change. This is because research has repeatedly shown that human behaviors are clearly leading to changes in earth's atmosphere. Since the Industrial Revolution, humans have been adding more greenhouse gases like carbon dioxide to the atmosphere, primarily by extracting and burning fossil fuels like coal, oil, and gas. These rapid increases in greenhouse gases have caused the climate to warm abruptly. In fact, climate models suggest that human contributions to greenhouse gases can explain virtually all of the temperature change since 1950.

We also know that climate change is happening because we have seen the effects of greenhouse gases increasing all across the globe. Glaciers are shrinking and causing sea levels to rise. Arctic sea ice is disappearing. In the spring, snow melts sooner and plants flower earlier. Animals are moving to higher elevations and latitudes to find cooler conditions. Droughts, floods, and wildfires have all gotten more extreme. Measurements collected over the last six decades by oceanographic expeditions and networks of floating instruments show that every layer of the ocean is warming up as carbon dioxide levels increase at a historically unprecedented pace. And even though there have been some memorable snowstorms in recent years, winters are actually warming across the world. Climate scientists' models predicted many of these changes, and our observations now show that these models were accurate.

Climate scientists continue to predict a range of possible future changes in temperature, precipitation, and other important variables due to climate change. These predictions will depend largely on human behaviors and for this reason, scientists might discuss their findings as "tentative" or use more uncertain language. But this does not undermine their confidence that humans are the primary cause of climate change, and that human behavior will continue to contribute to climate change. Through climate scientists' hard work, we know that the extent of the effects will depend on how we act to address human behaviors that cause climate change.

Control Text 1

Please carefully read the following text.

Much of what is known about climate change is published in scientific journals. This allows climate scientists to read each other's work and examine what evidence says about the causes of climate change.

Climate scientists know that humans cause climate change. This is because research has repeatedly shown that human behaviors are clearly leading to changes in earth's atmosphere. Since the Industrial Revolution, humans have been adding more greenhouse gases like carbon dioxide to the atmosphere, primarily by extracting and burning fossil fuels like coal, oil, and gas. These rapid increases in greenhouse gases have caused the climate to warm abruptly. In fact, climate models suggest that human contributions to greenhouse gases can explain virtually all of the temperature change since 1950.

We also know that climate change is happening because we have seen the effects of greenhouse gases increasing all across the globe. Glaciers are shrinking and causing sea levels to rise. Arctic sea ice is disappearing. In the spring, snow melts sooner and plants flower earlier. Animals are moving to higher elevations and latitudes to find cooler conditions. Droughts, floods, and wildfires have all gotten more extreme. Measurements collected over the last six decades by oceanographic expeditions and networks of floating instruments show that every layer of the ocean is warming up as carbon dioxide levels increase at a historically unprecedented pace. And even though there have been some memorable snowstorms in recent years, winters are actually warming across the world. Climate scientists' models predicted many of these changes, and our observations now show that these models were accurate.

Climate scientists continue to predict a range of possible future changes in temperature, precipitation, and other important variables due to climate change. These predictions will depend largely on human behaviors and for this reason, scientists might discuss their findings as "tentative" or use more uncertain language. But this does not undermine their confidence that humans are the primary cause of climate change, and that human behavior will continue to contribute to climate change. Through climate scientists' hard work, we know that the extent of the effects will depend on how we act to address human behaviors that cause climate change.

Control Text 2

Please carefully read the following text.

Much of what is known about climate change is published in scientific journals. However, it can be difficult for many people to read this information because climate scientists' articles are difficult to access.

More than half of all academic papers, including key research by climate scientists contributing to our understanding of climate change, are published by commercial publishers. Many times, reading these articles requires a costly journal subscription that few can afford. People who work for large organizations, including universities and government agencies, may be able to access them through their employers. Additionally, many college students can access them through school. But for most people, even those

who study climate change, access to these articles is restricted and requires a cost-prohibitive subscription.

As an alternative, climate change experts are increasingly trying to engage in “open access” practices in science. This means they pay money in publication fees up front, which allows others to access their studies for free. However, these scientists have to be able to afford this cost to make their research available to everyone at no cost. It often costs thousands of dollars to publish one article openly. In response, publishers of these journals have recently started to create deals with universities to allow faculty and students to publish research openly without these high costs. Several university systems and library systems now pay these publishers in advance so that their faculty and students can publish their research without paying high open access costs. Staff and students are also able to access the articles from that publisher through this agreement.

Climate scientists continue to publish research using open access practices. This includes agreements with publishers and participation in open access projects. These are all steps toward public access to scientific information on topics like climate change. It will allow many people to access important climate change papers that would allow them to understand that humans are the primary cause of climate change, and that human behavior will continue to contribute to climate change. Through climate scientists’ hard work, we know that the extent of the effects will depend on how we act to address human behaviors that cause climate change.

For the next, and final, part of this survey, you will be asked to respond to six questions.

1. How certain are you, if at all, that human activity is causing changes to the world’s climate? (4 = Very, 3 = Moderately, 2 = Slightly, 1 = Not at all)
2. Please explain why you selected [your selection] for the previous question ("How certain are you, if at all, that human activity is causing changes to the world’s climate?"). [Open-ended question]
3. To what extent, if at all, do you trust that the text you read is a reliable source of information? (4 = Very, 3 = Moderately, 2 = Slightly, 1 = Not at all)
4. Please explain why you selected [your selection] for the question "To what extent, if at all, do you trust that the text you read is a reliable source of information?". [Open-ended question]
5. To what extent, if at all, do you believe what the text is saying? (4 = Very, 3 = Moderately, 2 = Slightly, 1 = Not at all)
6. Please explain why you selected [your selection] for the question "To what extent, if at all, do you believe what the text is saying?". [Open-ended question]

Appendix I :

Experiment 1 Norming Study 2 Procedure

Thank you for taking the time to participate in this survey. This survey should take approximately 15 minutes to complete.

On the next page, you will see a screenshot of an article from a science museum website that talks about the process of climate science. Please carefully read the article.

Experimental Text

Uncertainty in Climate Science

Many people believe that knowledge about climate change is constantly changing. However, this is not true. Much of what we know about climate change has been repeatedly tested, analyzed, and supported through decades of observation and experimentation. Thousands of studies have scrutinized evidence from environmental research and formed a body of facts; these findings continue to support our understanding as to how humans are causing rapid warming and what its impacts will be.

While most people accept the reality of anthropogenic (or human-caused) climate change, many of these people are still uncertain about the strength of the science supporting it. This uncertainty has various causes, including media attention on contrary findings; political disagreements about the extent of negative future impacts; and “bad actors” who benefit from fostering public uncertainty, such as companies that burn fossil fuels to maximize their profits—all of which influences public climate change inaction.

In reality, climate scientists have been building on each other’s work since the early 1800s to generate testable explanations for changes to the environment and atmosphere. The methods for generating and testing explanations have been improved through technology and shared publicly so that they can be evaluated by the community of climate scientists and the public at large. Through this process, researchers have continually tested their understanding of climate change to see if findings hold up to scrutiny, or if alternative explanations may exist. This has significantly reduced the uncertainty, and we now know unequivocally that climate change is happening.

We also know that it’s going to get worse. Through research, we know that by 2050, the global average temperature will rise to somewhere between 2.6°C to 3.9°C (4.9°F to 7.0°F). In the best-case scenario of a 4.9°F global temperature increase, there would be higher extreme temperatures, longer heatwaves, and more flooding and drought. For humans, this would cause decreases in food security and water supply. It would also lower yields of maize, rice, wheat, soy, and lead to negative effects on livestock including changes in feed quality, spread of diseases, and limitations in water resource availability. In the worst-case scenario of a 7.0°F global temperature increase, some places on earth would no longer be livable due to extreme temperatures, flooding, and other natural disasters. There would be massive population displacement and unprecedented death rates due to hunger, disease, and violence over resources. The extinction of some animals, such as different bee species, would lead to the extinction of plant species that

depend on bees for pollination, leading to other extinctions and ecological changes as well as the depletion of human food sources.

Future temperature change due to climate change is presented as a range because data have some variability, and changes in human behavior in the coming days, months, and years can impact the outcome. The multitude of research has reduced the uncertainty so thoroughly that the chance of being wrong about climate change's causes and impacts is infinitesimal. Climate change is happening, and we know the damages have been severe. The changes to weather we have been experiencing recently are what was predicted years ago by climate scientists. However, not all hope is lost—research also shows that humans can still take concrete steps to lead the world toward the best-case scenario. What happens next will depend on whether we listen to the research and act on scientists' solutions.

Please answer the following 6 questions. If you strongly agree with a statement, select 10; if you strongly disagree, select 1. If you more or less agree with a statement, select the number between 1 and 10 that best expresses your belief.

1. What is considered to be certain knowledge about climate today, may be considered to be false tomorrow.
2. Certain knowledge about climate is rare.
3. The results of climate research are preliminary.
4. Theories about climate can be disproved at any time.
5. The knowledge about issues concerning climate is constantly changing.
6. Problems within climate research do not have any clear and unambiguous solution.

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1. To what extent, if at all, do you believe what the article is saying? (4 = Very, 3 = Moderately, 2 = Slightly, 1 = Not at all)
2. Please explain why you selected [your selection] for the question "To what extent, if at all, do you believe what the article is saying?". [Open-ended question]
3. To what extent, if at all, do you trust that the article you read is a reliable source of information? (4 = Very, 3 = Moderately, 2 = Slightly, 1 = Not at all)
4. Please explain why you selected [your selection] for the question "To what extent, if at all, do you trust that the article you read is a reliable source of information?". [Open-ended question]

The purpose of the article on this museum website is to help people understand that, although climate science is complex, there is less uncertainty about it than some may believe.

1. Do you find that the article does this effectively? Please explain why or why not. For reference, the article is provided again below. [Open-ended question]
2. What could be improved in this article? [Open-ended question]

Appendix J :

Experiment 1 Pilot Study Procedure

Consent form (see full text in Appendix A)

1. Do you agree to be in this study?
   - Yes
   - No

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2. What is your Prolific ID? Please note that this response should auto-fill with the correct ID

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3. What is your age? (in years)
4. Which of the following languages are you fluent in?

Options included: Rather not say, Afrikaans, Albanian, Amharic, Arabic, Armenian, Basque, Bengali, Belarusian, Burmese, Bulgarian, Catalan, Czech, Chinese, Croatian, Danish, Dari, Dzongkha, Dutch, English, Esperanto, Estonian, Faroese, Farsi, Finnish, French, Gaelic, Galician, German, Greek, Hebrew, Hindi, Hungarian, Icelandic, Indonesian, Inuktitut, Italian, Japanese, Khmer, Korean, Kurdish, Laotian, Latvian, Lappish, Lithuanian, Macedonian, Malay, Maltese, Nepali, Norwegian, Pashto, Polish, Portuguese, Romanian, Russian, Scots, Serbian, Slovak, Slovenian, Somali, Spanish, Swedish, Swahili, Tagalog-Filipino, Tajik, Tamil, Thai, Tibetan, Tigrinya, Tongan, Turkish, Turkmen, Ukrainian, Urdu, Uzbek, Welsh, Vietnamese, Telugu, Papiamento, Twi, Cantonese, Mandarin, Hakka, Malayalam, Gujarati, Punjabi, Other

5. Do you believe in climate change?
   - Yes
   - No
   - Don't know
   - Not applicable / rather not say

Issues concerning climate are highly topical and often mentioned in the media. We can read daily about issues such as climate change, pollution of the atmosphere, global warming, extreme weather, rise in ocean levels, and melting of ice in polar regions. This is material that we often encounter in newspapers and magazines, as well as on TV and radio. Most people who do research on climate have a background in natural science, for example in chemistry, biology, or meteorology. The following questions concern knowledge about climate and how one comes to know about climate. There are no right or wrong answers to these questions; it is your personal beliefs that interest us.

Topic-Specific Epistemic Belief Questionnaire (see full text in Appendix B)

Climate Change Concept Inventory (see full text in Appendix C)

Experimental Text (see full text in Appendix F) or **Control Text** (see full text in Appendix G)

Now that you have read the text, please answer the following questions about knowledge in climate science. If you strongly agree with a statement, select 10; if you strongly disagree, select 1. If you more or less agree with a statement, select the number between and that best expresses your belief.

Topic-Specific Epistemic Belief Questionnaire (see full text in Appendix B)

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1. How does sunlight affect temperature on Earth?
    - Sunlight warms the air directly, but the air does not warm the land.
    - Sunlight warms the land directly, but the land does not warm the air.
    - Sunlight warms the air directly, and the air warms the land.
    - Sunlight warms the land directly, and the land warms the air.
    - I do not know.

2. How much incoming sunlight do greenhouse gases absorb?
    - Greenhouse gases absorb almost no incoming sunlight.
    - Greenhouse gases absorb about half of the incoming sunlight.
    - Greenhouse gases absorb most incoming sunlight.
    - I do not know.

We thank you for your time spent taking this survey. Your response has been recorded.

You may download a copy of the consent form by clicking on the link below or request a copy from the researchers by contacting us at zdawc@umn.edu.

IRB Consent Form

You will now be redirected back to Prolific to confirm study completion.

Appendix K :

Experiment 1 Study Procedure

Part 1

Consent form (see full text in Appendix A)

1. Do you agree to be in this study?
   - Yes
   - No

---

2. What is your Prolific ID?

On the next page, you will see an article from a science museum website. Please carefully read the article. Please note that you will not be able to return to the article once you leave that page.

Experimental Text (see full text in Appendix F) or Control Text (see full text in Appendix G)

Topic-Specific Epistemic Belief Questionnaire (see full text in Appendix B)

Climate Change Concept Inventory (see full text in Appendix C)

Demographic Questions (see full text in Appendix E)

We thank you for your time spent taking this survey. Your response has been recorded.

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IRB Consent Form

You will now be redirected back to Prolific to confirm study completion.

Part 2

Consent form (see full text in Appendix A)

1. Do you agree to be in this study?
    - Yes
    - No

---

2. What is your Prolific ID?

Topic-Specific Epistemic Belief Questionnaire (see full text in Appendix B)

Please read each of the following questions carefully. Choose the one answer that most closely aligns with your understanding of climate science.

3. How does sunlight affect temperature on Earth?
    - Sunlight warms the air directly, but the air does not warm the land.
    - Sunlight warms the land directly, but the land does not warm the air.
    - Sunlight warms the air directly, and the air warms the land.
    - Sunlight warms the land directly, and the land warms the air.
    - I do not know.
4. How much incoming sunlight do greenhouse gases absorb?
    - Greenhouse gases absorb almost no incoming sunlight.
    - Greenhouse gases absorb about half of the incoming sunlight
    - Greenhouse gases absorb most incoming sunlight.
    - I do not know.

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IRB Consent Form

You will now be redirected back to Prolific to confirm study completion.

Appendix L :

Multiple Texts on Climate Change

Please read the following seven short texts. Each text is an article from one of the following resources:

- science museum
- scientific government agency website
- scientific school textbook
- scientific news article

The texts may have been adapted only to shorten the length of the article without changing the meaning.

Text A

Human activities release a variety of gaseous waste products. People once thought that the vast atmosphere could absorb these materials indefinitely, but we now know that our actions can lead to **climate change,** a directional change to the global climate that lasts for three decades or more (as opposed to short-term changes in the weather). As the concentrations of CO2 and other greenhouse gases rise, more solar heat is retained, thereby increasing the temperature of our planet. So far, Earth has warmed by an average of 1.1°C (2°F) since 1900. Much of this warming has occurred recently: 19 of the 20 warmest years on record occurred from 2002 to 2021.

As our planet warms, the climate is changing in other ways as well: Wind and precipitation patterns are shifting, and extreme weather events are occurring more often. At current rates, global models predict that Earth's temperature will rise by an additional 3°C (5°F) by the end of the 21st century.

Global models are constructed using data on factors that affect the absorption of solar radiation at Earth's surface. Adding greenhouse gases to the atmosphere increases the absorption of solar radiation, leading to global warming. Each year, large amounts of data on natural and human factors that affect the absorption of solar radiation are entered into the model, which then sums their effects to predict Earth's temperature.

But why go to all this trouble developing models? The reason is that we have only one Earth and hence cannot perform experiments to determine how emitting different amounts of CO2 affects the temperature of our planet. Instead, because we know that global climate models yield accurate predictions, we can use the models to perform "if-then" thought experiments: *If* we add a certain amount of CO2 to the atmosphere, *then* global temperatures will rise by a certain number of degrees.

If we continue with "business as usual," by 2100 Earth's temperature will likely be 4°C higher than it was in 1900. Moreover, even if all CO2 emissions were to stop immediately, the temperature of our planet would continue to rise because it takes decades for the CO2 already emitted to warm the oceans, and thus that long for the full effect of past emissions to be realized.

We will need many approaches to slow global warming and other aspects of climate change. Quick progress can be made by using energy more efficiently and by replacing fossil fuels with renewable solar and wind power and, more controversially, with nuclear power. Today, coal, gasoline, wood, and other organic fuels remain central to industrialized societies and cannot be burned without releasing CO2. Stabilizing CO2 emissions will require concerted international effort and changes in both personal lifestyles and industrial processes.

Progress toward finding solutions to address climate change was made in 2015 when all nations agreed to take steps to reduce CO2 emissions in the Paris Agreement. However, a 2021 report by the United Nations indicates that governments are not on target to meet the goals set. This lack of progress highlights a potential difference between what we know and what we choose to do. An overwhelming amount of evidence indicates that climate change is real, that the rise in global temperatures since the 1950s was caused primarily by human actions, and that there will be negative consequences for human societies and all life on Earth unless we act now. What we choose to do with this information is up to us.

Source: Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Orr, R. B., & Campbell, N. A. (2021). Chapter 56: Conservation Biology and Global Change. In *Campbell Biology* (12th ed., pp. 1260–1287). Pearson.

Text B

Although certain parts of the U.S. have undoubtedly experienced strong heat waves this summer, there's no reason to believe these weather events are evidence that the world is hurtling toward a climate change catastrophe. In fact, the best available evidence suggests that heat waves recorded a century ago were more problematic than anything we're seeing today.

Government researchers have been tracking heat waves for more than 100 years. According to data from the U.S. Climate Change Science Program, which is made available by the Environmental Protection Agency, the annual heat wave index for the contiguous 48 states was substantially higher in the 1930s than at any point in recent years. In some years in the 1930s, it was four times greater or even more.

Additionally, the National Oceanic and Atmospheric Administration (NOAA) has a large database of daily temperatures that goes back to 1948. NOAA used 1,066 weather stations located across the U.S. to collect this data.

According to NOAA, huge swaths of the U.S. have experienced a significant *decrease* in abnormally hot days recorded since 1948, especially in the Midwest and northern and eastern Texas.

Although it's true that some parts of the U.S. have seen the number of hotter-than-usual days increase over the past 70 years — including in California and the New York metropolitan area, both of which happen to be areas where a large number of media outlets are located — most weather stations have shown no meaningful changes or even declines.

Source: Haskins, J. (2023, July 27). *It's not climate change that's causing heat waves this summer, but no one wants to explain why*. Fox News.

https://www.foxnews.com/opinion/not-climate-change-causing-heat-waves-this-summer-explain

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Text C

Scientists are observing changes in the Earth's climate in every region and across the whole climate system, according to the latest Intergovernmental Panel on Climate Change (IPCC) Report, released today. Many of the changes observed in the climate are unprecedented in thousands, if not hundreds of thousands of years, and some of the changes already set in motion—such as continued sea level rise—are irreversible over hundreds to thousands of years.

However, strong and sustained reductions in emissions of carbon dioxide (CO2) and other greenhouse gases would limit climate change. While benefits for air quality would come quickly, it could take 20-30 years to see global temperatures stabilize, according to the IPCC Working Group I report, Climate Change 2021: the Physical Science Basis, approved on Friday by 195 member governments of the IPCC, through a virtual approval session that was held over two weeks starting on July 26.

"This report reflects extraordinary efforts under exceptional circumstances," said Hoesung Lee, Chair of the IPCC. "The innovations in this report, and advances in climate science that it reflects, provide an invaluable input into climate negotiations and decision-making."

The report provides new estimates of the chances of crossing the global warming level of 1.5°C in the next decades, and finds that unless there are immediate, rapid and large-scale reductions in greenhouse gas emissions, limiting warming to close to 1.5°C or even 2°C will be beyond reach.

The report shows that emissions of greenhouse gases from human activities are responsible for approximately 1.1°C of warming since 1850-1900, and finds that averaged over the next 20 years, global temperature is expected to reach or exceed 1.5°C of warming. This assessment is based on improved observational datasets to assess historical warming, as well progress in scientific understanding of the response of the climate system to human-caused greenhouse gas emissions.

"This report is a reality check," said IPCC Working Group I Co-Chair Valérie Masson-Delmotte. "We now have a much clearer picture of the past, present and future climate, which is essential for understanding where we are headed, what can be done, and how we can prepare."

Source: The Intergovernmental Panel on Climate Change. (2021, August 9). *Climate change widespread, rapid, and intensifying*. The Intergovernmental Panel on Climate Change. https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/

Text D

The rise in Earth's average surface temperature during the past 100 years is often referred to as global warming. Scientists have been studying this change and the

possible causes of it. In 2007, the Intergovernmental Panel on Climate Change (IPCC), an international organization created to study global warming, concluded that most of this temperature increase is due to human activities. These activities include the release of increasing amounts of greenhouse gases into the atmosphere through burning fossil fuels and large-scale cutting and burning of forests. Although many scientists agree with the IPCC, some scientists propose that global warming is due to natural climate cycles.

Gases in the atmosphere that absorb Earth's outgoing infrared radiation are greenhouse gases. Greenhouse gases help keep temperature on Earth warm enough for living things to survive. Without greenhouse gases, the average temperature on Earth would be much colder, about -18C. Carbon dioxide (CO2), methane, and water vapor are all greenhouse gases.

Carbon dioxide enters the atmosphere when fossil fuels, such as coal, oil, and natural gas, burn. Burning fossil fuels releases energy that provides electricity, heats homes and buildings and powers automobiles.

Deforestation is the large-scale cutting and or burning of forests. Forest land is often cleared for agricultural and development purposes. Living trees remove carbon dioxide from the air during photosynthesis. Cut trees, however, do not. Sometimes cut trees are burned to clear a field, adding carbon dioxide to the atmosphere as the tress burn. According to the Food and Agriculture Organization of the United Nations, deforestation makes up about 25 percent of the carbon dioxide released from human activities.

Carbon dioxide also occurs naturally in the atmosphere. Its sources include volcanic eruptions and forest fires. Cellular respiration in organisms contributes additional CO2.

The burning of fossil fuels releases more than just greenhouse gases into the atmosphere. Aerosols, tiny liquid or solid particles, are also released. Most aerosols reflect sunlight back into space. This prevents some of the Sun's energy from reaching Earth, potentially cooling the climate over time.

A changing climate can present serious problems for society. Heat waves and droughts can cause food and water shortages. Excessive rainfall can cause flooding and mudslides. However, climate change can also benefit society. Warmer temperatures can mean longer growing seasons. Farmers can grow crops in areas that were previously too cold. Governments through the world are responding to the problems and opportunities created by climate change.

Source: Anderson, M., Berwald, J., & Bolzan, J. F. (2017). Recent Climate Change. In *Integrated iScience, Course 2* (1st ed., pp. 668–674). McGraw-Hill Education.

Text E

Though we often think about human-induced climate change as something that will happen in the future, it is an ongoing process. Ecosystems and communities in the United States and around the world are being impacted today.

Global temperatures rose about 1.98°F (1.1°C) from 1901 to 2020, but climate change refers to more than an increase in temperature. It also includes sea level rise, changes in weather patterns like drought and flooding, and much more. Things that we depend

upon and value — water, energy, transportation, wildlife, agriculture, ecosystems, and human health — are experiencing the effects of a changing climate.

The impacts of climate change on different sectors of society are interrelated. Drought can harm food production and human health. Flooding can lead to disease spread and damages to ecosystems and infrastructure. Human health issues can increase mortality, impact food availability, and limit worker productivity. Climate change impacts are seen throughout every aspect of the world we live in. However, climate change impacts are uneven across the country and the world — even within a single community, climate change impacts can differ between neighborhoods or individuals. Long-standing socioeconomic inequities can make underserved groups, who often have the highest exposure to hazards and the fewest resources to respond, more vulnerable.

The projections of a climate change-impacted future are not inevitable. Many of the problems and solutions are known to us now, and ongoing research continues to provide new ones. Experts believe there is still time to avoid the most negative of outcomes by limiting warming and reducing emissions to zero as quickly as possible. Reducing our emissions of greenhouse gases will require investment in new technology and infrastructure, which will spur job growth. Additionally, lowering emissions will lessen harmful impacts to human health, saving countless lives and billions of dollars in health-related expenses.

Source: National Oceanic and Atmospheric Administration. (2021, August 13). *Climate Change Impacts*. National Oceanic and Atmospheric Administration. https://www.noaa.gov/education/resource-collections/climate/climate-change-impacts

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Text F

Climate change is often cast as a prediction made by complicated computer models. But the scientific basis for climate change is much broader, and models are actually only one part of it (and, for what it's worth, they're surprisingly accurate).

For more than a century, scientists have understood the basic physics behind why greenhouse gases like carbon dioxide cause warming. These gases make up just a small fraction of the atmosphere but exert outsized control on Earth's climate by trapping some of the planet's heat before it escapes into space. This greenhouse effect is important: It's why a planet so far from the sun has liquid water and life!

However, during the Industrial Revolution, people started burning coal and other fossil fuels to power factories, smelters and steam engines, which added more greenhouse gases to the atmosphere. We know this is true thanks to an overwhelming body of evidence that begins with temperature measurements taken at weather stations and on ships starting in the mid-1800s. Later, scientists began tracking surface temperatures with satellites and looking for clues about climate change in geologic records. Together, these data all tell the same story: Earth is getting hotter.

This warming is unprecedented in recent geologic history. A famous illustration, first published in 1998 and often called the hockey-stick graph, shows how temperatures remained fairly flat for centuries (the shaft of the stick) before turning sharply upward (the blade). It's based on data from tree rings, ice cores and other natural indicators. And the basic picture, which has withstood decades of scrutiny from climate scientists and

contrarians alike, shows that Earth is hotter today than it's been in at least 1,000 years, and probably much longer.

In fact, surface temperatures actually mask the true scale of climate change, because the ocean has absorbed 90 percent of the heat trapped by greenhouse gases. Measurements collected over the last six decades by oceanographic expeditions and networks of floating instruments show that every layer of the ocean is warming up. According to one study, the ocean has absorbed as much heat between 1997 and 2015 as it did in the previous 130 years.

We also know that climate change is happening because we see the effects everywhere. Ice sheets and glaciers are shrinking while sea levels are rising. Arctic sea ice is disappearing. In the spring, snow melts sooner and plants flower earlier. Animals are moving to higher elevations and latitudes to find cooler conditions. And droughts, floods and wildfires have all gotten more extreme. Models predicted many of these changes, but observations show they are now coming to pass.

Source: Rosen, J. (2021, April 19). *The Science of Climate Change explained: Facts, evidence and proof*. The New York Times. https://www.nytimes.com/article/climate-change-global-warming-faq.html#link-77e98c1e

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Text G

For the past several years, a small group of scientists has warned that sometime early this century, the rate of global warming might accelerate. And now, after what is poised to be the hottest year in recorded history, the same experts believe that it is already happening.

In a paper published last month, climate scientist James E. Hansen and a group of colleagues argued that the pace of global warming is poised to increase by 50 percent in the coming decades, with an accompanying escalation of impacts.

But not everyone agrees. University of Pennsylvania climate scientist Michael Mann has argued that no acceleration is visible yet in a blog post. Many other researchers also remain skeptical, saying that while such an increase may be predicted in some climate simulations, they don't see it clearly in the data from the planet itself. At least not yet.

In the early and mid-20th century, developed countries were so heavily polluted that the world was warming slowly. The record shows that the pace of warming clearly sped up around the year 1970. Scientists have long known that this acceleration stems from a steep increase in greenhouse gas emissions, combined with efforts in many countries to reduce the amount of sun-reflecting pollution in the air. Since the 1970s and 80s, however, the influence of aerosol pollution has leveled off, thanks in part to policies like the U.S. Clean Air Act Amendments of 1990. At the same time, greenhouse gas emissions have climbed. The result is a planet that is warming much faster now than in the first half of the 20th century.

But the data is murkier when it comes to whether the pace of warming over the past few decades has quickened even more — an increase that could accelerate the wildfires, floods, heat waves and other impacts around the globe. It may require more years of evidence to clear the statistical hurdles that climate science demands.

“I think we probably need maybe three or four more years" of data, said Chris Smith, a climate scientist at the University of Leeds. “It’s just a bit too early right now.”

Scientists are wary, in part, because some had reached the opposite conclusion roughly a decade ago. Back then, a few scientists and many political commentators that the rate of climate change had stalled or was slowing down. “Trying to estimate the underlying rate of warming from a short time period is really hard,” said Andrew Dessler, a climate scientist at Texas A&M University. “Just because you get a trend that looks like it’s really rapid — that doesn’t tell you what the underlying rate of warming is.”

Source: Mooney, C., & Osaka, S. (2023, December 26). *Is climate change speeding up? here’s what the science says.* The Washington Post. https://www.washingtonpost.com/climate-environment/2023/12/26/global-warming-accelerating-climate-change/

Appendix M :

Expressive Task

Please answer the following questions based on the texts you just read. You can use the following links to open/download the texts (depending on your settings) and reference them while you complete the questions.

- Text A
- Text B
- Text C
- Text D
- Text E
- Text F
- Text G

1. Explain the relationship between human activity and climate change.

   Responses were coded to how well participants explain the issue and integrate different perspectives discussed in the texts, with scores on this question ranging from 0 (no response or irrelevant information) to 6 (mentioning the two perspectives and providing elaborate explanation or reason for one or both, as well as relating the two perspectives to each other by comparing and/or contrasting them and trying to reconcile them).

2. There are different views on the relationship between human activity and climate change. Describe important differences between these views.

   The coding scheme for this question was scores ranging from 0 (mentioning no perspective, only one perspective, or providing irrelevant information) to 4 (mentioning the two perspectives and providing explanation or reason for both of them).

3. Could more than one view on the relationship between human activity and climate change be correct? Yes or no? If no, why not? If yes, why?

   First, we recorded whether participants recognize that the two perspectives were not mutually exclusive or might be reconciled (i.e., whether they answered "yes" or "no"). Second, we assessed to what extent participants explain and reconcile the two perspectives (i.e., when they answered "yes") and to what extent they select one of the perspectives and provide explanation or reason for that (i.e., when they answered "no"). Scores ranged from 0 (only answering "no" to the first question) to 5 (answering "yes" to the first question and mentioning the two perspectives and providing elaborate explanation or reason for one or both as well as relating the two perspectives to each other by explaining how they may be reconciled).

Appendix N :

Receptive Task

Choose the answer which you think best completes each statement using the information you have read. You can use the following links to open/download the texts (depending on your settings) and reference them while you complete the questions.

- Text A
- Text B
- Text C
- Text D
- Text E
- Text F
- Text G

1. Text A's mention of increasing global temperatures and Text G's discussion on the acceleration of global warming both highlight the importance of immediate action to address climate change impacts.
   True
2. Text B and Text G agree that heat waves and extreme weather events are becoming more frequent and severe due to climate change.
   False
3. Text C's findings on the expected continuation of sea level rise due to climate change are supported by Text G's discussion of long-term global warming trends and their impacts.
   True
4. Both Text G and Text D acknowledge that human activities contribute significantly to global warming and that this warming has accelerated in recent decades.
   True
5. Text E's data on the decrease of abnormally hot days in certain regions of the U.S. supports Text G's cautionary stance on declaring an acceleration in the pace of global warming.
   True
6. Text F’s discussion of the unprecedented nature of recent global warming aligns with Text G's consideration of a potential acceleration in the pace of global warming.
   True
7. Text A and Text F both assert that climate change is a recent phenomenon that has only begun in the past 70 years.
   False
8. Text F and Text B agree that the recent heat waves are a clear indicator of a global climate change catastrophe.
   False

9. Text F and Text C agree that Earth's temperature is rising at an unprecedented rate, with Text C providing a timeline for potential temperature stabilization with emissions reductions.
   True
10. Text F’s reference to Earth’s current temperature being the hottest in at least 1,000 years is supported by Text D’s statement that most of the temperature increase in the last 100 years is due to human activities.
   True
11. Text E, which shows a significant decrease in abnormally hot days since 1948 in parts of the U.S., directly contradicts Text F's assertion that Earth is getting hotter based on geologic records and other indicators.
   False
12. Text A's explanation of the causes of climate change aligns with Text E's findings of a decrease in abnormally hot days in certain regions, suggesting a consensus on the natural variability of climate events.
   False
13. Text B's emphasis on historical heat waves being more problematic aligns with Text E, which indicates a significant decrease in abnormally hot days since 1948 in some regions of the U.S.
   True
14. Text C and Text E both suggest that significant reductions in greenhouse gas emissions could limit future climate change, despite historical variations in temperature patterns.
   True
15. Text D's explanation of climate change, emphasizing human contributions, contradicts Text E’s discussion showing regional decreases in abnormally hot days since 1948.
   False
16. Both Text D and Text A suggest that the rise in Earth’s average surface temperature is a recent phenomenon primarily due to natural climate cycles.
   False
17. The assertion from Text D that most of the recent global warming is due to human activities contradicts the suggestion from Text B that current heat waves are not out of the ordinary compared to past events.
   True
18. Text C and Text D both support the idea that global warming is primarily due to natural climate cycles rather than human activities.
   False
19. Both Text C and Text A indicate that current global warming trends are part of natural climate cycles rather than being human-induced.
   False
20. Text C's findings on the likelihood of exceeding 1.5°C of warming align with Text B's implication that current climate conditions are not unprecedented.
   False

21. Text A's emphasis on the recent rapid increase in Earth's temperature due to human activities contradicts Text B's implication that current climate events, like heat waves, are not unprecedented or particularly alarming compared to historical events.
    True

Appendix O :

Experiment 2 Study Procedure

Consent Form (see full text inAppendix A)

1. Do you agree to be in this study?
   - Yes
   - No
2. We care about the quality of our study data. For us to conduct valid research to answer our research questions, it is important that you provide thoughtful answers that you generate on your own (without assistance from others or technology) to each question in the survey. Do you commit to providing thoughtful answers to the questions in this survey?
   - I can't promise either way
   - Yes, I will
   - No, I will not

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3. What is your Participant ID? Please note that this response should auto-fill with the correct ID.

On the next page, you will see an article from a science museum website. Please carefully read the article.

Experimental Text (see full text in Appendix F) or **Control Text** (see full text in Appendix G)

Expressive Task (see full text in Appendix M)

Receptive Task (see full text in Appendix N)

Demographic Questions (see full text in Appendix E)

We thank you for your time spent taking this survey. Your response has been recorded.

You may download a copy of the consent form by clicking on the link below or request a copy from the researchers by contacting us at zdawc001@umn.edu.

IRB Consent Form

You will now be redirected back to Prolific to confirm study completion.

Appendix P :

Experiment 3 Study Procedure

Part 1

Consent Form (see full text in Appendix A)

1. Do you agree to be in this study?

- Yes
- No

2. We care about the quality of our study data. For us to conduct valid research to answer our research questions, it is important that you provide thoughtful answers that you generate on your own (without assistance from others or technology) to each question in the survey. Do you commit to providing thoughtful answers to the questions in this survey?

- I can't promise either way
- Yes, I will
- No, I will not

---

3. What is your Participant ID? Please note that this response should auto-fill with the correct ID.

On the next page, you will see an article from a science museum website. Please carefully read the article.

Experimental Text (see full text in Appendix F) or **Control Text** (see full text in Appendix G)

Expressive Task (see full text in Appendix M)

Receptive Task (see full text in Appendix N)

Topic-Specific Epistemic Belief Questionnaire (see full text in Appendix B)

Climate Change Concept Inventory (see full text in Appendix C)

Demographic Questions (see full text in Appendix E)

We thank you for your time spent taking this survey. Your response has been recorded.

You may download a copy of the consent form by clicking on the link below or request a copy from the researchers by contacting us at zdawc001@umn.edu.

IRB Consent Form

You will now be redirected back to Prolific to confirm study completion.

Part 2

Consent Form (see full text in Appendix A)

1. Do you agree to be in this study?
   - Yes
   - No
2. We care about the quality of our study data. For us to conduct valid research to answer our research questions, it is important that you provide thoughtful answers that you generate on your own (without assistance from others or technology) to each question in the survey. Do you commit to providing thoughtful answers to the questions in this survey?
   - I can't promise either way
   - Yes, I will
   - No, I will not

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3. What is your Participant ID? Please note that this response should auto-fill with the correct ID.

Topic-Specific Epistemic Belief Questionnaire (see full text in Appendix B)

You may download a copy of the consent form by clicking on the link below or request a copy from the researchers by contacting us at zdawc001@umn.edu.

IRB Consent Form

For participants who were asked to read multiple short texts in addition to the first museum website article, please find the references for the original texts below.

Text A
Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Orr, R. B., & Campbell, N. A. (2021). Chapter 56: Conservation Biology and Global Change. In Campbell Biology (12th ed., pp. 1260–1287). Pearson.

Text B
Haskins, J. (2023, July 27). It's not climate change that's causing heat waves this summer but no one wants to explain why. Fox News. https://www.foxnews.com/opinion/not-climate-change-causing-heat-waves-this-summer-explain

Text C
The Intergovernmental Panel on Climate Change. (2021, August 9). Climate change widespread, rapid, and intensifying. The Intergovernmental Panel on Climate Change. https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/

Text D
Anderson, M., Berwald, J., & Bolzan, J. F. (2017). Recent Climate Change. In Integrated iScience, Course 2 (1st ed., pp. 668–674). McGraw-Hill Education.

Text E
National Oceanic and Atmospheric Administration. (2021, August 13). Climate Change Impacts. National Oceanic and Atmospheric Administration. https://www.noaa.gov/education/resource-collections/climate/climate-change-impacts

Text F
Rosen, J. (2021, April 19). The Science of Climate Change explained: Facts, evidence and proof. The New York Times. https://www.nytimes.com/article/climate-change-global-warming-faq.html#link-77e98c1e

Text G
Mooney, C., & Osaka, S. (2023, December 26). Is climate change speeding up? here's what the science says. The Washington Post. https://www.washingtonpost.com/climate-environment/2023/12/26/global-warming-accelerating-climate-change/

You will now be redirected back to Prolific to confirm study completion.