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FORUM

Unclouding judgment: advocating for greater attention to cognitive biases in socioscientific decision-making on climate change

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Abstract
This forum reflects on Chrystalla Lymbouridou's article titled "Science for ethics in SSI discussions." The author examined how students used scientific claims to support ethical decision-making in the socioscientific contexts of cloning, hunting, and mobile phone use. Drawing on a quotation, we critically discuss the role of cognitive biases in socioscientific decision-making, focusing on the context of climate change. First, we discuss the role of personal experience and intuition when reasoning about climate change and explore the extent to which it is constrained by our human-centered perspective. We then examine whether statistical evidence can prevent cognitive biases and show how cognitive biases can also influence the selection and interpretation of statistical evidence. Next, we consider whether and to what extent cognitive biases represent a danger, recognizing that some biases may serve as leverage points for climate action, while others can contribute to inaction in this area. Finally, the inevitable influence of these biases on understanding and decision-making leads us to the conclusion that they constitute a particularly important area of concern for both science education and science education research.

Keywords Socioscientific issues · Decision-making · Cognitive biases · Climate change

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Introduction

The article by Chrystalla Lymbouridou (this issue, 2025), on which this contribution is based, impressively examines how students use of scientific claims to construct and justify moral judgments, we have opted for a broader view on socioscientific decision-making in the context of socioscientific issues. One of the study's findings was that when statistical evidence was available, students used this information to assess the potential risks and benefits of a course of action and to predict whether certain outcomes were likely to occur or not. Building on this, the author concludes that when such evidence is lacking, students might resort to more intuitive assessment processes:

"Given the absence of statistical evidence, personal experiences, intuition or isolated anecdotes inform decision-making with the danger of leading students to cognitive biases related to the generalization of claims and misconceptions" (Lymbouridou, this issue, 2025).

This sentence has sparked a lively discussion among us that we would like to expand in this article. With one of us having a research background in socioscientific decision-making and climate literacy and the other one researching intuitive thinking in the context of evolution education, where cognitive biases are more commonly discussed, we quickly came to question how these types of expertise could benefit from each other and dived deeper into three questions: (1) What does it mean to rely on personal experiences or intuition in the context of climate change-related decision-making? (2) Does the lack of statistical evidence lead to greater reliance on cognitive biases? And if so, (3) do cognitive biases really pose a danger? All three questions will be addressed later in this article after providing a brief outline of the broader context. However, before doing so, we would like to make two preliminary remarks. First, we are aware that one could criticize that our contribution is based on one isolated sentence from Lymbouridou's manuscript, thereby disregarding the broader context in which this sentence is embedded. We do this because this sentence has inspired our discussion and structured our thoughts particularly well, but we do realize that this does not do justice to the complexity, numerous facets, and insights of her work. Secondly, while Lymbouridou's manuscript focuses in particular on the use of scientific claims to construct and justify moral judgments, we have opted for a broader view on socioscientific decision-making.

Aim of this contribution

Given the pressing problems humanity is facing, such as biodiversity loss and increasing risk of pandemics (e.g., McDermott 2022), negotiating science-related issues of societal relevance (i.e., socioscientific issues; Sadler 2004) is an important skill for the 21st century. Socioscientific issues are characterized by their inherent complexity and ill-defined nature, which is why decision-making on these problems is generally considered cognitively demanding and requires analytical thinking (see Fang, Hsu and Lin 2019). However, when making decisions about complex issues, individuals automatically resort to intuitive thinking patterns and cognitive biases (e.g., Evans 2010). These cognitive tendencies are present in all of us from an early age (Diamond and Kirkham 2005). They are inherent to human cognition, enable us to quickly grasp and process large amounts of information on a superficial level and streamline retention, recall, and retrieval of information (e.g., Shtulman 2017). However, despite being an efficient mode of reasoning, intuitive thinking can lead to systematic restrictions in negotiation: Although we strive to make rational, objective decisions, we remain susceptible to systematic thinking errors that can ultimately lead to suboptimal outcomes (Tversky and Kahneman 1986), like irrational behavior concerning societally relevant issues (e.g., Johnson and Levin 2009). If science education truly aims to enable learners to critically reflect, address, and act upon socioscientific issues, it seems essential to also provide opportunities for students to ponder their cognitive biases that influence their negotiation processes. Although cognitive biases have been researched in certain areas of science education, for instance evolution (e.g., Coley and Tanner 2012) and genetics (e.g., Nehm 2025), studies that have investigated their role in addressing and negotiating socioscientific issues appear to be limited (Note: A Google Scholar search in June 2025 yielded only about 40 hits when searching for the combination "cognitive biases" and "socioscientific decision-making").

The present article offers an attempt to approach this intersection, advocating that cognitive biases should be given greater consideration in science education (see also, for example, Nehm 2025). In particular, we build upon findings from prior research that the unique characteristics of complex issues make them particularly susceptible to systematic errors in thinking (e.g., Korteling, Paradies, and Sassen-van Meer 2023) and argue that using socioscientific issues in science class can be a promising opportunity to discuss the use, benefits, and pitfalls of cognitive biases as well as their impact on decision-making. To contextualize our reasoning, we will use climate change as an example of a particularly pressing socioscientific issue.

Socioscientific decision-making in science education

In light of the rapid scientific progress of the past 25 years (e.g., advances in mRNA vaccines and fusion energy) as well as various planetary crises, the question of what it means to be literate in science has been repeatedly discussed and further developed over the past few decades (for an overview of different conceptions, see Osborne 2023). A common approach to structuring the meaning of science literacy is based on three (rather idealized) visions, which can be summarized in a highly condensed and simplified form as follows: *Vision I science literacy* places a priority on preparing students for a future career in science and, therefore, emphasizes the acquisition of science content, concepts, and practices (Roberts 2007). *Vision II scientific literacy* aims to provide students with science learning that is situated in everyday contexts to prepare them for informed participation in societal decision-making (Roberts and Bybee 2014). More recently, this functional notion of scientific literacy has been further developed within *Vision III scientific literacy* to take a more critical stance by problematizing science, its processes, and its application with the aim of empowering students to respond critically to sociopolitical problems (Sjoström and Eilks 2018).

Since Vision II and Vision III are increasingly given more importance in science education, new frameworks and pedagogical approaches have gained more traction, with the socioscientific issues movement probably among the most important. Socioscientific issues, which are referred to here in their function as specific types of science-related problems of social significance, can provide an opportunity to develop the ethical dimension of science and scientific practice, thereby bringing aspects of character formation in science education to the fore (Zeidler 2014). These issues are characterized by their controversial and ill-structured nature, which means that the desired outcome is often not clearly defined, there is no universally agreed-upon solution, and different interest groups can have different (conflicting) values that must be considered. Conclusively, negotiating them requires the conscious integration of descriptive and normative components (Zeidler and Sadler 2023). Given these characteristics, typical socioscientific issues could stimulate classroom discussions about the necessity, impact, and acceptability of animal testing or, as in Lymbouridou's article, the decision-making about cloning, hunting, or mobile phone use.

Due to their inherent complexity, decision-making in socioscientific contexts is considered particularly challenging (see Fang, Hsu and Lin 2019). To better understand how students can be supported in this process, research in the field of science education has already provided numerous insights into students' reasoning processes (e.g., Sadler and Zeidler 2005), their construction and evaluation of arguments (e.g., Evagorou, Jiménez-Aleixandre and Osborne 2012), and their use of different decision-making strategies, such as weighing up different options or applying cut-off thresholds (e.g., Gresch, Hasselhorn, and Bögeholz 2011).

Unsurprisingly, the role of science knowledge in students' socioscientific decision-making has been of particular interest in many previous studies. For example, it has been shown that an increase in science content knowledge has a positive—albeit nonlinear—effect on argumentation quality (Sadler and Fowler 2006; for more insights on the role of science knowledge, see also Jia and Ren, 2025). Science knowledge, generally, is considered indispensable for understanding the scientific mechanisms and processes underlying these issues. However, due to their socioscientific complexity, these issues also challenge us to balance different values, reflect on (moral) convictions, take (conflicting) interests into account, and deal with uncertainties (Zeidler and Sadler 2023). In addition, some of these issues may evoke emotional reactions or create tension with previously held beliefs (e.g., Herman, Zeidler, and Newton 2020). The resulting high cognitive load during negotiations places high demand on our information processing capacities and can, therefore, reinforce the use of (less resource-intense) mental shortcuts, including cognitive biases (e.g., Evans 2010; Kahneman 2012). Based on these considerations, we argue that socioscientific issues offer a particularly valuable opportunity to address cognitive biases in science education.

The role of cognitive biases in socioscientific decision-making

In science education research, there are numerous studies providing insights into students' reasoning and potential challenges during negotiation, as well as frameworks designed to analyze and support informed decision-making. Those frameworks are often rooted in psychological research on individual decision-making processes (e.g., Fang, Hsu and Lin 2019; Wu and Tsai 2007). In order to make a rational decision, Amos Tversky and Daniel Kahneman (1986) propose that, in theory, the decision problem must first be analyzed, including outlining all possible options and their potential outcomes, followed by an evaluation of those options to select the one with the highest subjective value (see *prospect theory*; Kahneman and Tversky 1979). Ola Svenson's *differentiation and consolidation theory* (1992) adds a third phase to this process where individuals reflect on their decision afterward (i.e., post-decision consolidation). However, when individuals face complex issues, the volume of information and the cognitive effort required to assess probabilities or make predictions under uncertainty often exceed the brain's processing capacity (Tversky and Kahneman 1981). Instead of taking all factors into account and weighing up all options against each other (i.e., analytical thinking), individuals, in reality, often resort to mental shortcuts, or heuristics (i.e., intuitive thinking), which simplifies and expedites the decision-making process (Tversky and Kahneman 1981). While analytical thinking is slower, more deliberate, cognitively demanding and is part of formal decision-making, intuitive thinking is characterized by fast, automatic, effortless processing and part of informal decision-making (Dauer et al. 2017; Kahneman and Frederick 2002). Decisions that were set off by cognitive shortcuts often deviate from rational judgments, meaning that parts of the given problem or the available information are given too much or too little weight, compared to objectively more rational judgments (Dauer et al. 2017; Kahneman and Frederick 2002). These systematic reasoning errors are known as cognitive biases. They are considered systematic because they follow predictable patterns (Coley and Tanner 2012). Even though all cognitive biases are rooted in psychological processes, they may exert their influence at different stages of cognition: They can affect processing and interpretation of information, attentional focus, information-seeking behavior, judgment and evaluation, or recall of information (e.g., Azzopardi 2021; Vedejová and Čavojová 2022). Over recent decades, researchers have not only identified numerous cognitive biases but also discussed how certain contexts or problem characteristics can be especially prone to specific biases (e.g., Berthet 2022; Pobiner, Watson, Beardsley and Bertka 2019). One of the contexts in which cognitive biases have been extensively studied is climate change, which will serve as the contextual focus of this contribution moving forward.

Climate change as a valuable socioscientific decision-making context

Climate change represents a socioscientific issue that is prominently studied in science education research (Kumar, Choudhary and Singhet 2024). Climate change is not a matter of opinion, but encompasses measurable physical, chemical, and biological processes, and their interactions within the larger climate system, that are being altered by human activity (IPCC 2023). For informed decision-making, students thus depend on a solid understanding of the climate system, human influences on the climate system, and the interactions between climate (change) and life on Earth (see U.S. Global Change Research Program 2009 and 2024). In terms of the normative dimension of climate change, the unequal distribution of responsibility, vulnerability, losses, opportunities, and resources in this specific socioscientific issue could raise questions relating, for instance, to intergenerational justice (e.g., Do we have a moral duty to reduce emissions today, even if it means sacrificing some economic growth to protect future generations?), intra-societal justice (e.g., How can climate policies be designed to avoid unfairly impacting low-income communities?), and international justice (e.g., Should countries with the highest historical emissions be required to fund climate adaptation in vulnerable nations?) (Deutscher Ethikrat 2024). Given its urgency and severity, climate change can trigger a range of emotions such as fear or guilt (e.g., Haugestad and Carlquist 2025; for an overview of different climate emotions, see Pihkala 2022). In addition, climate change is characterized by various aspects of uncertainty, such as those arising from feedback loops and tipping points (both natural and societal; e.g., Otto et al. 2020) or from different assumptions underlying climate and scenario modeling—all of which potentially contribute to the difficulty of decision-making (for further insights into students' conception of uncertainty in the context of climate change see, for example, Schauss and Sprenger 2021).

Paradoxically, although the vast majority of the population (e.g., European Union 2023), and young people in particular (e.g., InterClimate Network 2023), accept and are concerned about climate change, individual and collective climate actions remain inconsistent. A promising but, in our opinion, still under-researched approach in science education to further investigate this discrepancy could be to focus on cognitive biases, as these strongly influence information processing and, thus, estimates about urgency, responsibility, and risk, ultimately shaping decision-making regarding climate action (for an exception see, Clabaugh Howell and Holt 2024; a brief note on this sentence: Under-researched in contrast to, for example, psychology and political sciences, where cognitive biases in the realm of climate change and climate action have been more frequently discussed, e.g., Rabaa, Geisendorf and Wilken 2022).

Discussing cognitive biases in climate change-related decision-making

As previously stated, our contribution focuses on one particular statement of Lymbouridou's manuscript. We will critically examine this statement (adopting a devil's advocate stance) by posing questions about its underlying assumptions and implications, aiming both to synthesize existing insights into cognitive biases in the context of climate change-related decision-making and to generate or reinforce relevant perspectives (see Fig. 1).

First, we will discuss the role of "personal experience" and "intuition" on reasoning about climate change, and how it is constrained by our human-centered (i.e., anthropocentric) perspective. We will then explore whether "statistical evidence" can prevent cognitive biases and argue how cognitive biases can also impact the selection and interpretation of statistical evidence. Next, we will reflect on whether and to what extent cognitive biases represent a "danger," recognizing that some biases may serve as leverage points for climate action while others can contribute to inaction in this area. Finally, we will conclude this article suggesting possible directions for both science education and science education research.

Question 1: What does it mean to rely on personal experiences and intuition in the context of climate change-related decision-making?

As previously noted, intuitive thinking is an automatic response that provides quick orientation through heuristics and enables fast but informal decision-making (Dauer, Lute, and Straka 2017). These heuristics are shaped by prior experiences, which are inherently grounded in our human perspective. Anthropocentrism (i.e., the tendency to view and interpret the world primarily from a human-centered perspective) is not strictly defined

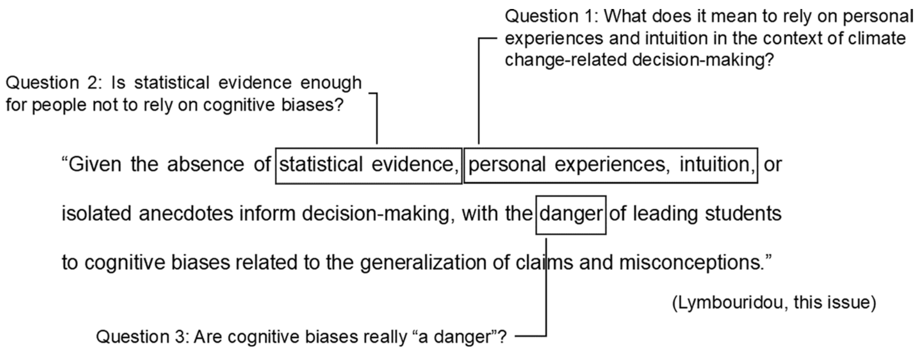

Fig. 1 Questions addressed in this contribution based on the selected quote

as a cognitive bias but is rather understood as a philosophical viewpoint or a set of beliefs that influence conceptualizations of the world (Davis and Arnocky 2024; Mylius 2018). In the field of science education research, anthropocentric thinking is described as a cognitive tool (e.g., Arenson and Coley 2018; Wu and Tsai 2011; Clabaugh Howell and Holt 2024) or a cognitive construal, which is "an intuitive, often implicit, way of thinking about the world [, …] a set of assumptions, a type of explanation, or a predisposition to a particular type of reasoning" (Arenson and Coley 2018, p. 254). Anthropocentric thinking already shows in childhood, as children often rely on human-centered analogical reasoning (Inagaki and Sugiyama 1988) and frequently categorize humans as distinct from other animals (Leddon, Waxman, Medin, Bang and Washinawatok 2012). Ben Mylius (2018) identifies three (not mutually exclusive) dimensions of anthropocentrism, each of which can contribute to distinct biases possibly influencing how climate change is understood and evaluated:

(1) *Perceptual anthropocentrism* refers to the fact that our understanding of the world is shaped by the information we humans are able to detect through our sensory organs and able to process through our language and cognition (Vollmer 1984): Human learning is primarily informed through sensory and motor experiences with the world (e.g., Lakoff and Johnsaon 1980), which are then generalized to different contexts. The phenomena that are accessible to us through our sensory organs are part of the mesocosm, which refers to the anthropocentric view of the world (Vollmer 1984). For instance, when reasoning about the justifiability of animal testing, one might draw from prior experiences in which one has felt pain oneself or seen or heard other people or animals suffering (for students' argumentation on animal testing, see, for example, Agell, Soria and Carrió 2014). In turn, the macrocosmos and microcosmos encompass parts of the world beyond our direct experience, like, for instance, climate change (Mylius 2018; Niebert and Gropengiesser 2013; a brief note on this sentence: Although we might be able to experience some aspects of climate change, e.g., some of its consequences such as extreme weather events, with our senses, the scale (geographically and temporally), complexity, and interconnectedness of the actual phenomenon far exceeds our perception. We can feel a hot day, but we cannot feel global warming). Information about such abstract concepts can only be conveyed through language or abstract formats, such as graphs, statistics, or scientific texts (e.g., Borghi, Binkofski, Castelfranchi, Cimatti, Scorolli, and Tummolini, 2017). However, humans tend to give more weight to information they experience first-hand (see Simonsohn, Karlsson, Loewenstein and Ariely 2008). This *experience effect bias* might help to explain why abstract issues like climate change are particularly susceptible to skepticism or disregard (Johnson and Levin 2009; see also the construct of psychological distance; Keller, Marsh, Richardson, and Ball 2022). More than 30 years ago, Kurt Pawlik (1991) pointed out that the mismatch between the temporal and spatial dimensions of human experience and the geologic scale of climate change leads to humans being unable "to respond adequately without the supportive means of information presentation and processing" (Pawlik 1991, p. 547). For example, although the continuing rise in global surface temperature (with a current increase of around 1.1 °C compared to pre-industrial levels; IPCC 2023) is conceptually imaginable, it appears negligible compared to the temperature fluctuations that humans are accustomed to between seasons or even within a single day. Pawlik (1991) refers to this discrepancy as the "low signal-to-noise ratio of global change" (p. 559). Conversely, researchers found that individuals who reported having experienced effects of climate change themselves (e.g., witnessing changes in seasons, wildlife populations, or public health) demonstrated heightened risk perception (Akerlof, Maibach, Fitzgerald, Cedeno and Neuman 2013; Choi, Gao and Jiang 2020), which has repeatedly proven to be a decisive factor for climate action (e.g., Brügger, Gubler, Steentjes and Capstick 2020). Furthermore, the

inability to perceive the scales of climate change also contributes to climate actions not being perceived as worthwhile as other, as the human reward system does not respond well to the delayed and vague gratification associated with them (i.e., climate actions might be perceived as ineffective due to the scale of their impact not being perceptible). In contrast, other environmental issues (e.g., pollution or deforestation) are more directly perceptible, and actions against them (e.g., litter picking or planting a tree) can produce immediate and visible results, making them psychologically more satisfying (Pawlik 1991).

(2) *Descriptive anthropocentrism* encompasses all forms of thinking that take the human species as a reference point (Mylius 2018). Within this framework, everything is interpreted in relation to humans, who are regarded as the central point of reference for understanding the world. Descriptive anthropocentrism can manifest in various forms. These include (a) viewing humans in isolation rather than in a broader geological, evolutionary, biosemiotic, or cosmological context, (b) valuing only those aspects of the universe that are perceptible to humans, (c) generalizing the human-specific features to universal principles and treating the human form as the standard against which all else is measured, (d) believing that humans are the end-product of evolution and no longer subject to it, or (e) assuming that humans are fundamentally different from and independent of nature (Mylius 2018). As a result, instead of being perceived as dependent from the biosphere, humans may see themselves as separate from nature (i.e., human exceptionalism) and, consequently, not as vulnerable to climate change (Betz and Coley, 2022) (see also *impact skepticism*; McCright 2016). For instance, Lizette Pizza and Deborah Kelemen (2023) found that beliefs in human exceptionalism were negatively associated with environmental moral concern. Conversely, attributing human characteristics to nature (i.e., anthropomorphism) was positively associated with seeing humans as part of nature, a view that, at least in children, correlated with stronger moral concern for the environment (Pizza and Kelemen 2023).

(3) Finally, *normative anthropocentric thinking* involves reasoning that privileges the human species (i.e., passive normative) or prescribes a superiority onto the human species (i.e., active normative) (Mylius 2018; see also Burchett 2014). This dimension of anthropocentrism can promote perspectives that prioritize human well-being or prosperity over the lives of other species, thereby instrumentalizing non-human nature not only to satisfy basic human needs but also to fulfill desires for further expansion and luxury (e.g., Almiron and Tafalla 2019). Normative anthropocentrism can also lead to the belief that humans will be less affected by climate change than other species due to a perceived superiority over nature. The assumption of human dominance might also lead to the conclusion that technological progress will be sufficient to address climate change-related challenges (Almiron and Tafalla 2019). Such beliefs can further reinforce inaction and reduce the perceived necessity of other climate actions (e.g., regulating population growth, limiting economic expansion, or promoting dietary changes) despite their potential to mitigate climate change (Almiron and Tafalla 2019).

In sum, understanding the world from an anthropocentric perspective, shaped by the limited data of our sensory organs, human-specific perceptions of space and time, cognitive frameworks, and human-favored attention and values, can lead to reasoning errors about the severity of climate change and a skewed perception of the importance and effectiveness of certain actions. However, it should be noted that some scholars have also criticized the tendency to blame anthropocentrism for humanity's destructive behavior (e.g., Burchett 2014; Droz 2022). These authors argue that it seems illogical to assume that a normative anthropocentric perspective would lead humans to engage in actions (or in the case of climate change also inaction) which ultimately harm humanity. Moreover, they raise doubts over the claim that humans, in general, would value humanity more than non-human nature. Instead, Kyle Burchett (2014) argues that certain (instrumentalized) parts of nature sometimes receive special value, rights, and protection because they can serve human interests such as economic gain (e.g., forests for timber and land for oil and mineral extraction). Other parts of nature, on the other hand, might be devalued if they do not serve these interests (e.g., destruction of deep-sea ecosystems through the use of large fishing nets dragged across the seabed). To address this contradiction, Burchett (2014) distinguishes two forms of anthropocentrism: *Ethical egoism* refers to behavior that aims to maximize individuals' short-term self-interest. Conversely, *genuine anthropocentrism* reflects a long-term concern for the collective well-being of humanity and would inherently encourage the protection of ecosystems and non-human species that contribute to human flourishing. Consequently, the root of inaction in the context of climate change may not be anthropocentrism itself, but rather *institutionalized* ethical egoism that prioritizes the interests of a small elite (for a critical discussion, see Droz 2022). This perspective is echoed by other scholars who link systemic inaction to broader political dynamics. For example, Aaron McCright and Riley Dunlap (2010) argue that political systems seeking to maintain the status quo often rely on the strategic use of biases, which can ultimately result in "non-decision-making" (see also Jacques, Dunlap and Freeman 2008). This leads to the next question as to whether providing statistical evidence could mitigate the effects of cognitive biases.

Question 2: Is statistical evidence enough for people not to rely on cognitive biases? Socioscientific decision-making involves both intuitive reasoning (i.e., based on heuristics and feelings) and evidence-based reasoning (i.e., based on data and logic) (Wu and Tsai 2011). Intuitive reasoning emerges as the first automatic response and cannot be suppressed (see Shtulman and Harrington 2016; Vosniadou 2019). Even though intuitive thinking is a valuable and resource-efficient mechanism in everyday decisions, informed decision-making requires analytical thinking and conscious effort to adopt a more objective perspective that extends beyond intuition and (anthropocentric) experiences (Höttecke, Hößle, Eilks, Menthe, Mrochen, Oelgeklaus and Feierabend 2010). Following Hans-Rüdiger Jungermann et al. (2005), Dietmar Höttecke and colleagues (2010) define different levels of judgment: Lower-level judgments are biased or stereotypical, whereas higher levels of judgment are characterized by the consideration and demand for evidence. Indeed, statistical evidence can provide an objective basis for evaluating claims (Reiss 2011). However, can we assume that simply providing objective evidence is sufficient to encourage students to engage in more deliberate, cognitively demanding analytical thinking and reduce reliance on intuitive reasoning?

On the one hand, statistical evidence may promote analytical thinking by encouraging evidence-based argumentation and can help make abstract phenomena more concrete. The value of evidence lies in its role as an objective standard, functioning as an "objective arbiter" in scientific and other controversies (Reiss 2011, p. 556). This is particularly important in discussions about complex and global issues, like climate change, that cannot be experienced through direct sensory perception but need to be conveyed via, for instance, text, numbers, or illustrations (see Question 1). Evidence plays a central role in helping students construct, question, and defend claims for negotiation (e.g., Roberts and Gott 2010). Promoting evidence-based reasoning can also help students to understand how scientific decisions are made by evaluating the evidence on which they are based (Zeidler and Nichols 2009). Moreover, evidence-based reasoning is linked to lower rejection of science, as well as reduced conspiracy beliefs, paranormal thinking, and susceptibility to fake news (Pennycook and Rand 2019; Rizeq, Flora and Toplak 2021).

On the other hand, the format in which the statistical evidence is presented can reinforce cognitive biases (e.g., *framing effect biases*), and personal opinions, views, and beliefs may still influence how the statistical evidence is recognized or interpreted (e.g., *confirmation biases*). The framing effect bias is one of the earliest documented cognitive biases and occurs when identical information is interpreted differently depending on its presentation (Tversky and Kahnemann 1986 and 1981). For example, people tend to prefer different options (e.g., certain vs. uncertain outcome) depending on whether they are framed as gains or losses, even though they would lead to the same outcome (i.e., people prefer options that are framed as certain rather than uncertain gains and uncertain rather than certain losses; Tversky and Kahnemann 1986 and 1981). In the context of climate change, research has shown that framing can influence attitudes, intentions, emotions, and even recall of climate information (for an overview see Homar and Cvelbar 2021). Loss frames are generally associated with fear and have proven effective in changing people's intentions and behaviors, such as increasing their willingness to sign a petition (Nabi et al. 2018). In contrast, gain frames are linked to hope, which can positively influence attitudes and beliefs, and they are particularly effective when combined with a prior loss frame (see emotional sequencing; Nabi et al. 2018). However, framing effects have also been shown to be context dependent. For example, people are more likely to support renewable energy policies when these are framed as gains for economic development rather than as measures to avoid losses, though this effect was not observed when the policies were framed in terms of energy costs (Bertolotti and Catellani 2014). Furthermore, a poll on climate messaging (EcoAmerica, Lake Research Partners, Krygsman, Speiser and Perkowitz 2015) showed that simply changing the wording of messages about climate change (e.g., using "damage the climate" instead of "climate change" or "outdated fuels" instead of "dirty energy") can significantly affect how those messages are received.

Knowledge about framing effect biases can be capitalized by both advocators and opponents of climate change actions, for instance, by framing statistical evidence in favor of their agendas (see Korteling, Paradies and Sassen-van Meer 2023). Students, in particular, may struggle to evaluate the reliability of sources or recognize the influence of an author's perspective (or agenda) on information presentation (Coiro et al. 2015). In turn, higher numeracy skills have been shown to reduce susceptibility to framing effects (Peters Västfjäll, Slovic, Mertz, Mazzocco and Dickert 2006). However, the interpretation of statistical evidence is not only vulnerable to external influences, such as how information is presented, but also to internal influences: Prior beliefs, for example, can influence how individuals attend to, trust, and interpret information, and can even diminish the impact of framing effects (Bertolotti Catellani and Nelson 2021). More precisely, research on motivated reasoning (also: motivated numeracy or motivated processing) in the context of climate change shows that people tend to interpret statistical evidence in ways that align with their existing views, selectively recall supportive information, and discount contradictory evidence (i.e., *confirmation bias*; Nurse and Grant 2020; Zappalà 2023). Political orientation can similarly shape how people interpret climate change-related language and messages (Schuldt and Roh 2014). Importantly, even individuals with high numeracy are not immune to these biases, but instead have shown to use their numeracy skills to defend their pre-existing attitudes (Kahan, Peters, Dawson and Slovic 2017 in the context of gun control).

To conclude, statistical evidence provides information and a broader perspective that is not readily accessible through individual experience. Statistical evidence, however, does not necessarily mitigate cognitive biases; instead, cognitive biases are unavoidable being an essential component of the reasoning process and can also (consciously or unconsciously) lead individuals to use statistical evidence in ways that reinforce pre-existing beliefs, either for themselves or to persuade others. So, when dealing with cognitive biases is unavoidable, this leads us to the final question of how dangerous those cognitive biases might really be.

Question 3: Are cognitive biases really "a danger"?

In considering whether cognitive biases pose "a danger" to climate change-related decision-making, we must first clarify what is meant by *danger*, as the definition will significantly shape the answer to this question. Climate change is a unique socioscientific issue in many respects. It is, for example, the result of cumulative human behavior and it therefore offers numerous opportunities for human intervention. So, the question might be interpreted as: Do cognitive biases jeopardize these intervention measures? The answer concerning this question is not straightforward. Some cognitive biases may indeed undermine climate action, while others could support it. For instance, anthropomorphism (i.e., attributing human-like qualities to nature) can foster empathy and motivate environmentally responsible behavior (Williams, Whitmarsh, and Chríost 2021; see also Question 1). Importantly, some scholars suggest that by being aware of cognitive biases (e.g., framing effect bias and experience effect bias) and their impact on decision-making, stakeholders could mitigate their negative effects and even transform them into leverage points for promoting climate action by strategically tailoring how information is presented (e.g., Korteling, Paradies and Sassen-van Meer 2023; Zhao and Luo 2021). This can be achieved, for example, by carefully framing climate change-related messages or by making climate change perceptible for the human senses via simulations, experience tanks, or computer games (Korteling, Paradies and Sassen-van Meer 2023).

However, several researchers argue that the main issue is not how people reason about climate change but that their reasoning, beliefs, and concerns do not translate into climate actions (e.g., Rabaa, Geisendorf and Wilken 2022). Thus, if we define socioscientific decision-making as the ability to make (more or less) rational choices informed by scientific evidence, rather than personal anecdotes or intuitive judgments, then we must ask: Are cognitive biases a danger to informed decision-making or to action following such decisions? Or (to put it more pointedly): Why do we often fail to act in a climate-friendly manner, even though we have the evidence to support these decisions?

As Simon Rabaa, Sylvie Geisendorf, and Robert Wilken (2022) note, engagement in climate action is often oversimplified as a matter of rational decision-making: Although there are already ample scientific models identifying the most effective and economically viable climate actions, these models are flawed in that they assume rational individual behavior (Rabaa, Geisendorf and Wilken 2022; Gsottbauer and Van den Bergh 2011). However, cognitive biases can prevent people from acting rationally or even in their own best interest, including economically (Rabaa, Geisendorf and Wilken 2022). As climate scientist Christian Jakob put it: "This insecurity [of human irrational behavior] is much larger than the uncertainty we have in the science" (Hannam 2021, as cited in Rabaa, Geisendorf, and Wilken 2022, p. 101).

One especially relevant category in this regard is *status quo biases*, which lead individuals to maintain existing behaviors, even when change would bring clear benefits (Samuelson and Zeckhauser 1988). These biases contribute to (1) underestimating the need for change, (2) avoiding personal responsibility, (3) perceiving change as overwhelming, (4) associating change with negative emotions, and (5) failing to question the current state of affairs (Rabaa, Geisendorf and Wilken 2022). Under the umbrella term of status quo biases, *normalcy bias* describes the tendency to extrapolate knowledge about the past to the future, assuming that the world is static and that current conditions represent a consistent state of homeostasis (see Korteling, Paradies and Sassen-van Meer 2023). This bias can lead people to underestimate the effect of climate change, like deflecting the possibility of weather extremes and disasters happening, or more readily accepting information that encourages people to disbelieve warnings or view future scenarios optimistically (also referred to as *optimism bias*). Normalcy bias could, therefore, dampen feelings of urgency, leading to inaction (Rabaa, Geisendorf and Wilken 2022).

The elaboration of these three questions leads to the conclusion that because cognitive biases inevitably influence our thinking, addressing them in science education is not only possible, but also necessary.

Implications for science education

In the previous sections, we have touched on just a few of the many cognitive biases that seem to be relevant in the process of climate change-related decision-making (e.g., Clabaugh Howell and Holt 2024; Frank, Henkel and Lysgaard 2024). They are prevalent in learners themselves and in sources of information or the public discourse. Therefore, bias-aware approaches in science education should involve reflecting cognitive biases at both the individual (e.g., learners' prior beliefs and the impact of cognitive biases on their reasoning processes and information behavior) and the collective level (e.g., the impact of message framing in climate change communication or the role of cognitive biases in sustaining misconceptions and inaction in the broader public). Addressing the multitude of cognitive biases in the science classroom may seem almost impossible. And yet, as they do not occur randomly but systematically (Tversky and Kahneman 1974), selecting and grouping them in pedagogically meaningful ways could hold great potential for classroom discussions to promote students' awareness of and reflection on the influence, benefits, and disadvantages of these cognitive constraints. Driven by ongoing progress in cognitive psychology, promoting students' metacognitive skills as a measure to teach abstract and counter-intuitive concepts and reduce the influence of intuitive thinking is gaining increasing attention in science education (Zohar and Barzilai 2013). In contrast with prior assumptions that intuition could be circumvented or overwritten by acquiring (contradicting) scientific knowledge, intuitive thinking remains the primary mode of reasoning, as it is an inherent part of human cognition and is also continuously reinforced by everyday experiences (Sthulman, 2022; Vosniadou 2019). As a result, the focus in science education research is shifting from merely teaching scientific concepts, and attempting to "convince" learners that their intuitive ideas about the world are wrong, to supporting students to develop metacognitive skills that help them understand and enable them to manage their intuitive thinking (González Galli, Peréz and Gómez Galindo 2020). Metacognition comprises (1) knowledge about cognition in general (i.e., about the processes behind thinking and knowing) (i.e., declarative metacognition), as well as (2) being aware of and able to regulate one's own thinking (i.e., procedural metacognition) (Kuhn and Dean 2004; see also Schraw 1998). In order to promote appropriate recognition and processing of evidence in the context of climate change, we agree with Helen Fischer and Dorothee Amelung (2025) that metacognition seems like a necessary skill to mitigate the effects of cognitive biases and motivated reasoning. Through the implementation of metacognitive training, students could learn about the characteristics of various cognitive biases, enabling them to recognize these biases, and subsequently be guided through a structured reflection on their own use of them (see Hartelt and Martens 2025, for the context of evolution).

To stimulate metacognitive discussions in the science classroom, we see potential, for instance, in using existing climate change education material for joint reflection on potential framings or hidden agendas. As outlined in a study by Emiliy Eaton and Nick Day (2020), educators and teaching materials predominantly portray individual climate action (primarily through changes in personal consumption behavior) as an appropriate and responsible response to climate change, and rarely address the role of collective action and structural changes. Although individual behavioral changes are essential to combat climate change (to a certain extent) (e.g., Pizziol and Tavoni 2024), too much focus on individual responsibility can lead to the role and power of corporate interest not being questioned, the necessary changes in social structures being obscured, and the momentum for societal transformation being lost (e.g., Shove 2010). In addition, as discussed in the work by Johanna Weselek (2024), class-specific prejudices will become entrenched as long as individual consumer choices remain at the center of these discussions. To critically discuss this framing of individual responsibility, the widespread implementation of carbon footprint calculators could be used: While such tools can certainly help raise awareness about personal carbon emissions, they have been heavily criticized for their strong focus on individual responsibility, lack of evidence of effectiveness, and the lack of transparency with regard to their data sources and existing controversies (DuPuis and Mulvaney 2024).

Reflecting on anthropocentrism could, for example, spark discussions about the limits of human perception being an obstacle to understanding and potentially to accepting climate change (perceptual anthropocentrism) or about the human-nature dualism as components of narratives about climate change (descriptive anthropocentrism). The latter may also be observed in teaching materials, as some have been found to convey an unnatural separation between human and non-human systems and describe a hierarchical relationship in which nature primarily serves human needs (e.g., Gugssa, Aasetre and Debele 2020 for Ethiopian textbooks). By critically examining such materials, students can discuss how the relationship with nature is framed and engage with questions about their own understanding of and appreciation for the natural world (see also Bonnett 2025). Building on the criticism that certain parts of nature are particularly valued when they serve human interests (see Question 1), Leonie Bossert and Lena Schlegel (2022) discuss that human lives might also be devalued or excluded within the same systems and according to the same logic of dominance. With regard to climate change, green colonialism can provide an example for this line of reasoning: In short, green colonialism describes the circumstance that powerful actors pursue (supposedly) climate change-related or environmental goals at the expense of Indigenous People and marginalized communities (e.g., taking land away from Indigenous communities in the name of carbon offset measures; Redvers, Chan, Odochao, Pratt, Sim, Gougsa, Kobei and Willetts, 2025). Decolonial climate education, an approach to climate education that has gained increasing attention in recent years, might offer a valuable space to question this reproduction of climate injustices and the possible link to anthropocentric beliefs (see, for example, Stein et al. 2023). This resonates with the broader call for more justice-oriented approaches in climate change education (e.g., Clark 2024; Leite 2024).

Implications for future research

To deepen our understanding of how students deal with cognitive biases in the science classroom, and how they reflect upon their own decision-making processes against the backdrop of these cognitive biases, we suggest that future research should include targeted intervention studies on the effectiveness of metacognitive awareness. In a first step, a potential study could investigate to what extent, for instance, anthropocentric beliefs are visible in students' socioscientific decision-making on climate change. In a second step, the implementation of a metacognitive training or systematic variations of metacognitive support could shed light on how metacognitive awareness can influence the quality of their climate change-related reasoning.

In this contribution, we explored a small selection of cognitive biases and the different ways they shape our understanding, perspectives, and decision-making without us realizing. Inevitably, this calls for closer inspection of how those and other biases that arise from individual cognition are also manifested and represented in our institutional and societal structures. Using the method of bibliometric analysis, Andrea Westphal and colleagues (2025) were recently able to show that gender inequalities are still not sufficiently addressed in climate change education, calling for more research by and with those whose perspectives have been underrepresented to date. Focusing on cognitive biases could be a promising and novel approach to centering inequalities in climate change education, for example, by exploring with students how biases affect various social groups in different ways. From this perspective, addressing cognitive biases in the classroom can open up a path for critical reflection on issues of climate justice.

Although this contribution focuses specifically on cognitive biases in climate change-related decision-making, an intersection that has received limited attention in science education to date, we would like to explicitly acknowledge and refer to the existing research on intuitive reasoning in the context of decision-making about socioscientific issues (e.g., Sadler and Zeidler 2005; Wu and Tsai 2007). In many cases, however, it remains somewhat vague what exactly intuitive thinking reflects (e.g., moral intuition, affective reasoning, or personal experience). For future research, it therefore seems useful to further refine the conceptual understanding of intuitive reasoning in the context of socioscientific decision-making, as a more precise conceptual differentiation between different components of intuitive thinking including cognitive biases could help to better orchestrate existing research findings.

Final remarks

In a climate-altered world, there lies great value in not only teaching about climate change, but also reflecting on our climate change-related decision-making. We would argue that cognitive biases in climate change-related decision-making (also indeed, in socioscientific decision-making in general) deserve a more central position in science education not only because learning about cognitive biases would provide learners with introspection on their own decision-making processes but also because it would provide them with a more nuanced understanding of how human cognition may be one of the contributing factors to the prevailing collective inaction in society. From this perspective, addressing cognitive biases in science education could contribute to scientific literacy Vision III by empowering students to critically reflect on how socioscientific issues are presented and taught and how their own assessment of these issues is influenced by intuitive thinking patterns. Despite the limitation that numerous cognitive biases and their influence on climate change-related decision-making could not be addressed within the scope of this article, this contribution aims to offer some initial thoughts in this direction. Finally, we would like to thank Chrystalla Lymbouridou, whose one sentence sparked hours of discussion, and we sincerely hope that the science education research community will take up this thread to jointly explore its potential for science teaching and learning.

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