

Generative AI in Climate Change Communication and Education

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Abstract: Climate communication faces challenges such as scientific complexity, misinformation or lack of personal connection that make it difficult for the public to understand and act on climate change in an informed way. This study was conducted to ascertain whether Generative AI may facilitate public understanding and reduce barriers to climate communication. Questions were asked to ChatGPT, that provided clear and informative answers, synthesising key concepts, clarifying doubts and excluding misinformation. Some answers were too brief or general, requiring more information. As Generative AI depends upon open access information, academia has a key role in ensuring availability of accurate science-based and policy-relevant knowledge.


1 INTRODUCTION


Climate change is one of the greatest challenges for humanity, with severe consequences, widespread impacts and risks predicted. The global temperature of the earth is rising, mainly due to human activities related with the emission of greenhouse gases. This global warming causes changes in the atmosphere, land and oceans and affects weather and climate extremes, with considerable damage to nature and people (IPCC, 2023b). The Paris Agreement (2015), signed by 195 countries, set a global target of limiting temperature rise to between 1.5°C and 2.0°C, which is not being met. A study based on 40.000 interviews with citizens of twenty countries (representing 72% of CO₂ emissions) showed that citizens had little willingness to reduce CO₂ emissions, namely driving less, reducing the heating and cooling of their homes, or limiting beef consumption. The lack of support for climate measures was related to a perception of economic regression, energy taxation and carbon pricing. An important finding was that informing the public about the mechanisms, individual costs and gains associated with climate measures significantly

increases their overall support (Dechezleprêtre et al., 2022). Hence, climate communication becomes essential to meet the goals of the Paris Agreement.

There are barriers and challenges to climate change communication, resulting in the topic being perceived as ambiguous, uncertain and complex, making the public understanding incomplete, distant in space and time, and disconnected from their personal experiences (Wibeck, 2014). These affect people's willingness to adopt climate-friendly practices. In traditional media, such as television and newspapers, the frequency of communication on climate change is uneven and unsystematic, marked by cyclical moments such as extreme weather events, conferences and political meetings, and the publication of scientific reports (Horta & Carvalho, 2017). The media's tendency towards alarmist and sensationalist reporting, combined with the journalistic pursuit of balance, often portrays climate sceptics and scientists as equal in number and influence (Wibeck, 2014), which doesn't accurately reflect the scientific consensus, given that over 95% of climate scientists attribute global warming to human activity (Cook et al., 2013). Interest in the

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topic varies across countries: it is higher in Portugal, Greece, and Chile, and lower in the United States, the United Kingdom, and Germany. The difference in interest is attributed to the effects of climate change felt in the first countries, such as major fires, but also to political polarisation. In the United States and Australia, where the left-right divide is more pronounced, people are generally less interested in climate change news (Newman et al., 2022). Two national surveys in China, in 2009 and 2016, show that Chinese people recognise the anthropogenic causes of climate change, strongly support government measures and are willing to take individual action. However, respondents consider it less urgent than air pollution (Liu, 2023).

News consumption habits are changing, with television losing ground to the internet. Young people, in particular, are using social networks as their main source of news, with X being the social platform most widely used for this purpose. Climate scientists are intensifying efforts in public engagement and communication, but they compete with a multitude of subjective opinions on social media, making it difficult to establish themselves as an expert authority (Alinejad & Van Dijk, 2023). Newman (2017) conducted a study consistent with these findings. When analysing the posts and most active actors on X during the release of the IPCC Fifth Assessment Report⁴, he concluded that the majority came from bloggers, activists and concerned citizens, suggesting that large audiences were more exposed to non-traditional voices than scientists. Also, Meyer et al. (2023) analysed the public discourse on X choosing five climate events from 2017 to 2021. Results showed that discussions were heavily politicised, frequently called for action while criticizing administrations, and highlighted potential negative future scenarios. The platform was centred around controversial debates and polarizing personalities such as G. Thunberg and D. Trump.

The role of online and social media in climate communication divides scholars: optimists highlight the potential of interactivity and audiovisual to enhance science communication and empower unprivileged groups, while pessimists warn of fragmentation and susceptibility to misinformation. The amount of online climate content is significant and increasing, but the quality of communication is poor, because climate scientists play a limited role in the social media debate. On other perspective, climate NGOs communicate extensively online to inform,

build support, change behaviour and mobilise action (Schäfer, 2012). For Bushell et al. (2017) climate communication is improving, but there is still a gap between awareness of scientific knowledge and action by governments, industry and people. Causes cited relate to the nature of the problem (e. g., long-term challenge requiring action now and lack of immediate evidence) and the narratives used to communicate, which are not effective in changing behaviour (e.g., doomsday and alarmism). A more recent paper (Brown et al., 2023) reported on the adoption of mitigation and adaptation actions by individuals, such as travelling by public transport and cycling, installing solar panels, switching to high efficiency vehicles or changing to a plant-based diet. However, the primary motivation was economic rather than environmental.

Interpersonal communication may also play a significant role in beliefs and feelings about climate change. Goldberg et al. (2019), in a survey of a nationally representative U.S. sample, found that discussing global warming with friends and family enhances knowledge on the topic, increases awareness of the scientific consensus on human-driven causes, and fosters further discussion and deeper engagement. Regarding the family, it is worth highlighting the role that children can play in transferring knowledge and changing their parents' attitudes. Lawson et al. (2019) conducted a study with 238 families over two years, in which middle school children received a climate change curriculum designed to promote intergenerational learning. The discussion between parents and children increased parents' concerns about climate change, especially among more conservative fathers. In fact, engaging in deliberative discussion is considered one of the most effective climate change education strategies (Monroe et al., 2019).

Generative AI (GenAI) brings new tools for climate change communication. GenAI refers to a class of artificial intelligence (AI) systems that can generate new data based on existing data, often using deep learning models. This means that the new content is not copied from the training data but is based on patterns and structures learned during the training process. GenAI can be applied to text generation. A prominent example is ChatGPT⁵, a large language model (LLM) that has been trained to produce text optimised for dialogue, using terabytes of data written by humans, and obtained from different sources such as websites, books and research articles. ChatGPT was chosen for this study by its prevalent use⁶. In January 2025, ChatGPT had around 3.66 billion visits per

⁴ IPCC Report <https://www.ipcc.ch/assessment-report/ar5/>

⁵ ChatGPT <https://chat.openai.com/>

⁶ <https://explodingtopics.com/blog/chatgpt-users> - Exploding Topics identifies and tracks emerging trends and

issues. Its trustworthiness is based on transparency (explanations of data collection and analysis), reputation and credibility. It is often cited by professionals and companies looking for market trends.

month. It is important to highlight that these LLM are trained solely on predictive tasks that do not require an understanding of meaning. This would involve linking linguistic forms to communicative intents, that these models currently are not equipped to do (Bender & Koller, 2020). ChatGPT answers use natural language processing techniques that makes the interaction sound like human conversation, even though it is artificial communication (Esposito, 2022). This versatile tool is being used for many applications, including the creation of stories, poetry, programming code, marketing campaigns, in scientific writing, translations and business predictions. It is also used as an advanced search tool that presents the results in a narrative way (Dwivedi et al., 2023).

Regarding climate, ChatGPT has the advantage of accessing large amounts of information, from various scientific disciplines such as atmospheric science, oceanography and ecology, to quickly relate seemingly independent information, in order to reach conclusions (Biswas, 2023) and present the most likely sequence of words based on its training data. In this way, it can present relevant and contextualised answers, synthesizing and explaining complex concepts (Haluza & Jungwirth, 2023). One good advantage is the capability of summarizing information from long texts, identifying key points and main themes to facilitate comprehension (Zhu et al., 2023). Because ChatGPT can store input/output responses, it enables continuous conversation (Dwivedi et al., 2023), making the experience more dynamic and interesting for the user. Immediate feedback makes it possible to clarify and deepen the topic in real time, as new questions arise. Due to its interactive nature, ChatGPT has great potential for active learning, as the user actively investigates the problem. ChatGPT can also be part of a scalable, tailored and automated climate communication, combined with other communication tools in a concerted intervention. It can be used to create articles with reasons for climate action, providing informative content on impacts and encourage behaviour change (Nisbett & Spaiser, 2023).

A growing body of studies has highlighted the relevance of using GenAI in the educational context. In a Harvard Business Review article (Acar, 2023), the author proposed the PAIR framework for using GenAI in education, emphasising the need to use AI in education, rather than prohibiting it. PAIR (Problem, AI, Interaction, Reflection) is designed to proactively integrate AI into students' curriculum, developing skills such as the ability to formulate problems, explore different AI tools, think critically and reflect on AI results. For students, chatbots have been

suggested to improve learning and motivation, as they can provide personalised learning experiences with content tailored to their needs and learning style (Kuhail et al., 2023). For teachers, GenAI can help to address science education topics such as climate change and be used as a tool for creating educational resources. A relevant example is given by Cooper (2023), who asked ChatGPT to create a teaching unit on renewable energy for seventh graders based on the 5E instruction model (Bybee et al., 2006). He obtained the design of a unit, divided into rubrics, with a sequence of activities for each phase (engage, explore, explain, elaborate, evaluate) and quizzes for a final (self-)evaluation. Content like this can benefit teachers with mixed views or limited understanding of climate change. In the USA, where only about half the population attributes climate change mainly to human activity, a national survey of science teachers revealed widespread gaps in training, knowledge, and awareness of the scientific consensus on anthropogenic global warming. This resulted in varied classroom approaches: 54% taught that climate change is mainly human caused, 31% presented mixed messages, 10% denied the issue, and 5% avoided it altogether (Plutzer et al., 2016).

It is important to recognize some limitations and ethical concerns associated with ChatGPT. It can generate inaccurate or false information, requiring fact-checking with reliable sources (Zhu et al., 2023). The quality of its output depends on the training data and using content without scientific verification risks perpetuating biases and inaccuracies. Therefore, it is recommended to use the generated content as a first draft, refined by specialists to ensure accuracy and relevance (Salvagno et al., 2023). A major concern is the risk of political bias. In several political orientation tests, ChatGPT was classified as having left-leaning political views. Political bias in a widely used tool can be harmful for society, as it can impact human perception and increase the spread of misinformation. Ethical AI should present balanced, neutral arguments based on available scientific evidence and not favour political viewpoints (Rozado, 2023). There is also the issue of plagiarism. When using ChatGPT we may not recognise and give due credit to the authors of the content (Cooper, 2023). Sometimes the tool is used to aid decision making, but it can be inconsistent and contradictory, yet people tend to trust and let their judgement be influenced by ChatGPT advice (Krügel et al., 2023). Trust in ChatGPT is a critical factor, as highlighted by Choudhury and Shamszare (2023) in a survey of 607 U.S. adults. Their findings suggest that trust significantly impacts adoption, with blind trust posing risks in decision-making and lack of trust

leading to underuse and missed opportunities. In education, the trend towards acceptance by students is noteworthy. A survey of university students in the USA found that 89% used ChatGPT for schoolwork, raising ethical concerns. While it can be used as a pedagogical complement that increases students' motivation and self-efficacy, it can also be used to produce homework, projects and reports, which can lead to more superficial learning and weaken critical thinking, challenging teachers' assessments (Yu, 2024). Another concern related to the origin of the training data is ChatGPT's ability to exclude manipulative information (Zhu et al., 2023). To mitigate this limitation and to ensure accuracy, relevance and coherence, ChatGPT is trained in a multi-stage process, using advanced machine learning techniques. It is pre-trained on a large internet corpus, fine-tuned with human supervision, to enhance the conversation. It also uses a Reward Model Construction, where the generated responses are reviewed and ranked by humans. Finally, the model uses a reinforcement learning technique called Proximal Policy Optimisation, which uses the reward model to maximise predicted quality and generate knowledgeable and contextually appropriate conversations (Zhu et al., 2023; OpenAI, 2023b). A final ethical issue relates to the carbon impact of ChatGPT due to its high energy consumption. GPT-3 training consumed approximately 190,000 kWh of energy and produced 85,000 kg of CO₂ (Quach, 2020). A study of the carbon impact of various GPT models, based on GPT3 and GPT2, aimed to determine the energy efficiency of each. The power (watts) used for each query varied between 48.9 and 61.7 (Everman et al., 2023). As a technology that is growing rapidly on the market, the environmental cost cannot be ignored.

2 OBJECTIVES AND METHOD

This exploratory study examines whether ChatGPT can generate information and explanations to support climate communication, to help people understand and act on climate change in an informed way, targeting the general public and the youth.

The research team is part of 'BESIDE', an ERA Chair in Research and Development in Environmental Economics, which aims to promote multidisciplinary research on topics related to climate change, sustainability and socio-economic sciences. One of the research areas is focused on science communication and literacy of related topics. With the rise of GenAI, the team aimed to explore its

impact on climate change communication and education.

Using its web interface, we created a set of generic prompts, designed to understand how ChatGPT generates answers about climate change, assuming that the general public and youth may rely on it to obtain information:

- What is climate change?
- What are the real problems associated with climate change?
- What can we do to reduce climate change?
- Is climate change a hoax?

We also used ChatGPT as a potential tool to support teachers by asking for suggestions on how to approach the topic with students. We selected the elementary and high school levels as these grades are identified as having most climate change education interventions (Monroe et al., 2019). Climate Change education should inform and prepare these generations to understand, make lifestyle changes and adaptations to reduce GhG emissions and other ongoing and upcoming impacts (UNESCO, 2010). The prompt was:

- How can I explain the concepts of climate change, climate adaptation and climate change mitigation with concrete examples to high school students versus elementary school students?

We conducted an initial session with ChatGPT-3.5 in August 2023, as it was the most accessible version but limited to pre-2021 data. In June 2024, we repeated the questions with ChatGPT-4.0, a more advanced version with improved data coverage, though still constrained by session length and response complexity. We then analysed differences between versions and compared with scientific publications and recent grey literature including reports from IPCC (2023b, 2023a), OECD (Dechezleprêtre et al., 2022) and UNESCO (2010). The complete references used for interpretation of results are available in the bibliography.

In the presentation of the results, ChatGPT responses are presented in figures, to better distinguish the generated text from the authors' text. The generated text was edited, cut to reduce the length. We present ChatGPT-4 responses (July 2024), as they are more recent, but for interpretation, answers from ChatGPT-3.5 (August 2023) were also consulted to verify consistency and evolution (completed answers available by emailing the authors).

Responses were evaluated based on relevance (whether the answers addressed the questions, matched the required knowledge level, and were clear for different audiences), completeness (whether they covered key scientific facts), and scientific accuracy (whether they aligned with peer-reviewed literature and official reports). Overall, our findings indicate that ChatGPT provides sufficiently relevant information for the intended audiences. Due to the characteristics of a LLM, repeating the questions to ChatGPT will not result in the same answers.

3 RESULTS

Figure 1 to Figure 5 present the answers from ChatGPT to the set of prepared prompts.

3.1 [Prompt 1] What Is Climate Change?

Climate change refers to significant and lasting changes in the Earth's climate, particularly in temperature, precipitation patterns [...] ranging from decades to millions of years. It can result from natural processes, such as volcanic eruptions [...] as well as from human activities, particularly the burning of fossil fuels and deforestation. Here are some key points:

1. **Greenhouse Effect:** Human activities, especially the burning of fossil fuels [...] and deforestation, have increased concentrations of greenhouse gases (GHGs) like carbon dioxide (CO₂) [...]. These gases trap heat in the atmosphere, leading to a warming effect known as the greenhouse effect.
2. **Temperature Rise:** [...] increase in global average temperatures [...] with the last few decades being the warmest on record.
3. **Sea Level Rise:** As temperatures rise, polar ice caps and glaciers melt, contributing to higher sea levels [...].
4. **Extreme Weather Events:** [...] increase in the frequency and intensity of [...] hurricanes, droughts, heatwaves, [...] devastating impacts on ecosystems and human societies.
5. **Ocean Acidification:** Increased CO₂ levels [...] dissolve in oceans, leading to ocean acidification [...] harm marine life [...] such as corals and some plankton species.
6. **Impact on Ecosystems:** [...] Species may be forced to migrate to new areas, adapt, or face extinction.
7. **Human Health and Socioeconomic Impact:** [...] increased heat stress, the spread of diseases, and food and water insecurity. [...] economic losses and social instability [...] on agriculture, infrastructure, and livelihoods.

Understanding and addressing climate change involves reducing GHG emissions (mitigation), adapting to its effects (adaptation), and enhancing resilience to its impacts through policy measures, technological innovations, and international cooperation.

Figure 1: Answer to prompt “What is Climate change?”

The first question was asked to understand how ChatGPT introduces climate change. The answer defines the term, presents causes and a few consequences, and briefly mentions the concepts of mitigation and adaptation. The information is relevant but not complete. Since the question was general, the answer remained broad, making it suitable for an initial approach. It also introduces terms like GHG and explains the greenhouse effect, which may be important for a better understanding and opens up possibilities to be explored with new prompts. There are some differences between answers from

ChatGPT-3.5 (2023) and ChatGPT-4 (2024). The language in version 3.5 was simpler and attributed the causes of climate change mainly to human activity, whereas the new version begins by mentioning that Climate Change can result from natural and human activities. This may lead to believe that these have equal importance, which is not accurate. However, throughout the explanation, the focus is indeed on anthropogenic causes. In 2023, the response included a call to action, adaptation and mitigation measures and a reference to the Paris Agreement, offering a broader perspective. The 2024 version presents a more direct answer to the question.

3.2 [Prompt 2] What Are the Real Problems Associated with Climate Change?

The second question intended to increase understanding of the problem of climate change and expand the first response, which ChatGPT did.

1. **Rising Temperatures:** [...] heat-related illnesses and deaths, particularly among vulnerable populations like the elderly and children.
2. **Sea Level Rise:** [...] threatens coastal communities with increased flooding, erosion, and the loss of habitat [...]. It can also lead to the displacement of populations and the loss of arable land.
3. **Extreme Weather Events:** [...] can cause significant damage to infrastructure, disrupt livelihoods, and lead to loss of life.
4. **Impact on Water Resources:** [...] more severe droughts [...] and increased flooding [...] affect freshwater availability for drinking, agriculture, and sanitation [...].
5. **Agricultural Disruption:** [...] alter growing seasons, reduce crop yields, and affect food security [...] reduce the predictability of food production, leading to higher food prices and increased hunger and malnutrition.
6. **Biodiversity Loss:** Many species are unable to adapt quickly [...] leading to shifts in distribution, population declines, or even extinction [...].
7. **Ocean Acidification:** [...] affects marine life [...] corals, mollusks, and some plankton species that rely on calcium carbonate to form their shells and skeletons.
8. **Health Impacts:** [...] spread of infectious diseases [...], worsening air quality (leading to respiratory issues) [...] can strain public health systems.
9. **Economic Costs:** [...] Damage to property and infrastructure [...], loss of agricultural productivity, and increased health care costs [...] reduced tourism revenues and increased costs for disaster relief and adaptation measures.
10. **Social and Political Instability:** [...] Resource scarcity [...] can lead to migration, social unrest, and even violent conflict over resources.
11. **Loss of Livelihoods:** [...] Climate change can disrupt fishing, farming, and forestry activities, leading to loss of income and increased poverty.
12. **Cultural Impacts:** [...] rising sea levels and extreme weather can damage historical monuments and archaeological sites, while changing environmental conditions can disrupt traditional ways of life.

Figure 2: Answer to prompt “What are the real problems associated with Climate Change?”

While the first answer focused on environmental and health problems, the second repeated information from the first answer, but went into more detail on the economic, social and cultural aspects, all connected with anthropogenic actions. The answer from ChatGPT-3.5 had minimal differences (e.g., the cultural impact was not mentioned, but all the other points were presented in both answers, although organised differently).

<p>Mitigation Strategies</p> <p>Reduce Greenhouse Gas Emissions: [...] Transition to Renewable Energy like solar, wind, hydroelectric, and geothermal power to reduce dependence on fossil fuels. [...] Improve energy efficiency in buildings, transportation, and industries. [...] Electrify transportation and other sectors currently dependent on fossil fuels. [...] Implement carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems, to incentivize the reduction of greenhouse gas emissions.</p> <ol style="list-style-type: none">1. Sustainable Agriculture and Forestry: [...] Reduce deforestation and promote reforestation and afforestation. [...] Adopt sustainable agricultural practices that reduce emissions, such as no-till farming, crop rotation, and organic farming. [...] Agroforestry: Integrate trees and shrubs into agricultural landscapes to enhance carbon sequestration.2. Carbon Capture and Storage (CCS): [...] Develop and deploy technologies that capture CO₂ directly from the atmosphere and store it underground. [...] Bioenergy with CCS (BECCS): Combine bioenergy production with carbon capture and storage to create negative emissions.3. Reduce Waste [...] Increase recycling rates and compost [...] to reduce methane emissions from landfills. [...] Promote a circular economy where products are designed for reuse, repair, and recycling, minimizing waste.4. [...] Support and strengthen international climate agreements, such as the Paris Agreement [...] Implement national policies and regulations that promote renewable energy, energy efficiency, and emissions reductions. <p>Adaptation Strategies</p> <ol style="list-style-type: none">1. Climate-Resilient Infrastructure: Building Standards [...] ensure infrastructure can withstand extreme weather events. Invest in flood defenses, such as levees, sea walls, and stormwater management systems.2. Implement water conservation practices [...] drought management plans to ensure water availability during dry periods.3. Agricultural [...] plant drought-resistant crop varieties. [...] Improve irrigation systems to use water more efficiently.4. Community Preparedness [...] Develop and implement emergency response plans [...] Increase public awareness and education [...] <p>Individual Actions</p> <ol style="list-style-type: none">1. Reduce Energy Consumption: [...] Improve home insulation, use energy-efficient appliances, and switch to LED lighting. [...] Use public transportation, carpool, bike, or walk instead of driving alone. Consider electric or hybrid vehicles.2. Sustainable Consumption: [...] Reduce meat and dairy consumption [...] Choose products with lower carbon footprints, avoid single-use plastics, and support companies with sustainable practices.3. Advocacy and Education: Raise Awareness, Educate others [...] advocate for strong climate policies. Political Engagement: Support and vote for leaders and policies that prioritize climate action. <p>Technological Innovation</p> <ol style="list-style-type: none">1. Invest in research and development of new technologies that can reduce emissions or help adapt to climate change.2. Accelerate the deployment of existing green technologies, such as renewable energy systems and electric vehicles. <p>International Cooperation</p> <ol style="list-style-type: none">1. Global Collaboration [...] share knowledge, technology, and resources.2. Provide financial support to developing countries for climate mitigation and adaptation efforts.

Figure 3: Answer to prompt “What can we do to reduce Climate Change?”

3.3 [Prompt 3] What Can We Do to Reduce Climate Change?

There were several differences between the 2023 and 2024 responses. In 2023, ChatGPT-3.5 provided a shorter response with mostly global actions and only one individual measure. It listed 13 actions without distinguishing mitigation from adaptation, and some points lacked detailed explanations.

In 2024, the ChatGPT-4 generated a longer list of measures but focused on giving instructions without explaining why they should be implemented. Additionally, some points such as ‘Choose products with lower carbon footprints’ were treated in a

superficial manner, which may make them difficult for the public to understand due to a lack of context or suitable explanation and may compromise behaviour change and action.

3.4 [Prompt 4] Is Climate Change a Hoax?

Climate change is not a hoax. The overwhelming consensus among scientists is that climate change is real, primarily caused by human activities, and has significant and measurable impacts on the planet. [...]

Scientific Consensus

1. Intergovernmental Panel on Climate Change [...] reports, which are compiled by hundreds of experts from around the world, conclude that climate change is happening, largely driven by human activities such as burning fossil fuels and deforestation.
2. [...] Major scientific organizations worldwide, including NASA, the National Oceanic and Atmospheric Administration (NOAA), the American Association for the Advancement of Science (AAAS), and the Royal Society, agree on the reality of climate change and its human causes.
3. [...] Thousands of peer-reviewed studies [...] provide robust evidence of climate change [...] data from various sources, including temperature records, ice cores, satellite observations, and climate models.

Evidence of Climate Change

1. [...] past few decades being the warmest on record [...] aligns with increased concentrations of greenhouse gases in the atmosphere.
2. Glaciers and polar ice caps are melting at an accelerating rate [...]
3. Sea levels have risen due to melting ice and the thermal expansion of seawater [...]
4. [...] extreme weather events [...] have increased. Climate change influences the severity and occurrence [...]
5. Oceans absorb about a quarter of the CO₂ emitted by human [...] leads to ocean acidification, which affects marine life [...].
6. Many species are shifting their geographical ranges, migration patterns, and seasonal behaviors in response to changing temperatures and habitats.

Addressing Skepticism

[...] arguments often stem from misunderstandings, misinformation, or vested interests in maintaining the status quo. Here are common rebuttals to skeptical claims:

1. Natural Variability: While natural factors do influence the climate, the rapid warming [...] cannot be explained by natural variability alone. Human activities are the primary driver of recent changes.
2. Historical Climate Changes: The Earth's climate has changed throughout its history, but the current rate of change is unprecedented [...]. Past changes were often driven by natural factors over much longer timescales.
3. Scientific Integrity: Climate science is subject to rigorous peer review and transparency. The scientific method involves constant testing, validation, and refinement of theories and data.

Climate change is supported by a vast body of scientific evidence [...]. Dismissing it as a hoax undermines efforts to tackle the significant challenges it poses.

Figure 4: Answer to prompt “Is climate change a hoax?”

This question was asked with the intention of understanding ChatGPT's responses to *fake news* and climate change conspiracy theories. The answer indicates that ChatGPT training attributes denial and scepticism about climate change to misinformation, vested interests and misunderstandings. It responded based on scientific consensus, pointed to the evidence to justify the veracity of the facts, and briefly explained why there are groups that deny climate change. Comparing responses from ChatGP-3.5 and 4, the latest version offers more developed and accurate content, mentioning different scientific

organisations and relevant scientific support and provides ways to refute sceptical claims.

3.5 [Prompt 5] How Can I Explain the Concepts of Climate Change, Climate Change Adaptation and Mitigation with Examples to High School Students versus Elementary School Students?

The answer supports initial learning of the topics proposed by the teacher by presenting essential content adapted to the students' schooling levels and age groups, using appropriate language and examples, aligned with contemporary theories of cognitive development and learning. The 2024 version is again more developed, introducing explanations, examples and discussion points on climate change, adaptation and mitigation. It concludes with pedagogical tips to tailor the complexity and examples to the appropriate school level. Limitations are addressed in the discussion.

4 DISCUSSION

In this study, we used ChatGPT to understand its potential contribution to climate communication, literacy and critical thinking, targeting the general public and also focusing on young students and teachers in the educational community. Some prompts were created to emulate what the common citizen could ask the free version of ChatGPT to get information about climate change. Simple questions with little context were deliberately asked to simulate this type of usage. The results allowed a qualitative evaluation of the relevance, accuracy and scientific acumen of ChatGPT replies to climate related questions and showed some aspects worth highlighting.

The user can obtain clear and general information about what climate change is and its main causes, but also more specific information about the consequences, adaptation and mitigation measures, as well as potential individual actions to take, related to

<p>High School Students:</p> <ul style="list-style-type: none"> Explanation: Climate change refers to significant changes in global temperatures and weather patterns over time [...] rapid increase in global temperatures largely due to human activities like burning fossil fuels, deforestation, and industrial processes. Example: [...] impact of the greenhouse effect. Explain how gases like carbon dioxide (CO₂) and methane (CH₄) trap heat in the Earth's atmosphere, leading to a rise in global temperatures. Use data and graphs showing rising global temperatures over the past century. Discussion Point: Talk about the melting of polar ice caps and glaciers, rising sea levels, and the increased frequency and intensity of extreme weather events, such as hurricanes, heatwaves, and floods. <p>Elementary School Students:</p> <ul style="list-style-type: none"> Explanation: Climate change means the Earth's weather is getting warmer or changing in other ways, and it's happening faster because of things people do. Example: Describe how burning things like coal, oil, and gas to run cars and factories puts more "bad" gases into the air. These gases act like a blanket, making the Earth warmer. Discussion Point: Talk about simple effects, like how polar bears' homes (ice) are melting and how this makes it hard for them to live. [...] how more wildfires can start because it gets too hot and dry. <p>Climate Change Adaptation</p> <p>High School Students:</p> <ul style="list-style-type: none"> Explanation: Climate change adaptation involves making adjustments in our social, economic, and environmental practices to minimize the damage [...]. Example: [...] building seawalls and levees to protect coastal cities from rising sea levels [...] developing drought-resistant crops to ensure food security in areas prone to drought. Discussion Point: [...] different countries [...] adaptation strategies based on their specific vulnerabilities and needs [...] Netherlands' extensive use of dikes and water management systems to prevent flooding. <p>Elementary School Students:</p> <ul style="list-style-type: none"> Explanation: Adaptation means changing how we live so we can handle the changes in the weather. Example: [...] in places where it's getting really dry, farmers are planting special plants that don't need as much water. In cities near the ocean, people are building big walls to keep the water out [...] Discussion Point: Use simple visuals, like pictures of drought-resistant plants or seawalls [...] <p>Climate Change Mitigation</p> <p>High School Students:</p> <ul style="list-style-type: none"> Explanation: [...] efforts to reduce or prevent the emission of greenhouse gases to slow down global warming. Example: [...] renewable energy sources [...] produce electricity without emitting greenhouse gases. [...] importance of energy efficiency, such as using LED lights and electric cars. Discussion Point: [...] international agreements, like the Paris Agreement, in setting targets for reducing emissions. [...] impact of individual actions, such as reducing meat consumption, using public transportation, and recycling. <p>Elementary School Students:</p> <ul style="list-style-type: none"> Explanation: Mitigation means doing things to stop climate change from getting worse. Example: [...] solar panels on houses can make electricity from the sun, which doesn't make "bad" gases. [...] planting trees helps because trees take in the "bad" gases and give us oxygen. Discussion Point: Show pictures or videos of wind turbines and solar panels. Encourage simple actions, like turning off lights when not needed and riding bikes instead of using cars. <p>Summary</p> <ul style="list-style-type: none"> High School: Provide detailed explanations with scientific terms, data, and real-world examples. Encourage critical thinking and discussion about global and local impacts and solutions. Elementary School: Use simple language, relatable examples, and visual aids. Focus on basic concepts and easy-to-understand impacts and actions.

Figure 5: Answer to prompt 5.

this topic. Accessible language, selection of essential information and clarity of content presentation are benefits commonly associated with GenAI (Biswas, 2023; Zhu et al., 2023) and also mentioned as good practices in various existing models of science communication (Longnecker, 2016).

The information presented is correct and relevant, with facts widely recognised in the scientific community (e.g., IPCC, NOAA). One aspect that caught our attention in Prompt 1 of ChatGPT-4 was the way it included natural and human causes for this phenomenon, but without developing the theme equally for both, providing only additional content for the anthropogenic related causes.

While the answer is not wrong, this may lead the public to consider natural and human causes with equal importance, which is not accurate, as the acceleration of climate change is mainly due to human activity (IPCC, 2023a). Nevertheless, in Prompts 4 and 5, the emphasis is again, and appropriately, only focused on human action.

Analysing the set of information resulting from Prompts 1 to 4 in terms of completeness, the information is sufficient for the objectives and the target, as a very detailed approach could overwhelm and demotivate this public. Regarding climate communication, Stoknes (2014) advises not to overwhelm people with the catastrophic scenarios but instead focus on a positive message of a greener future, in a smart society, using less resources and having a better quality of life. To understand perceptions of climate change and the factors influencing behaviour change, Dechezleprêtre et al. (2022) conducted a survey of 40000 respondents from 20 countries. They concluded that support for climate actions depends on beliefs about the effectiveness of the policy (in reducing emissions), concerns about inequality (impact on low-income households) and personal interests (impact on household). Explaining climate measures and their benefits to the citizens increases the willingness to support them, while simply informing about the impacts of climate change seems to be ineffective. But, as concluded by Robertson (2022, p. 57) 'Climate change is a difficult news topic to cover, and it is not clear that there is a one-size-fits-all approach to it'.

When addressing measures towards climate mitigation (i.e., enhance decarbonisation by reducing the GhG emissions) and/or adaptation (i.e., take actions to minimise present and future impacts)⁷ both collective and individual measures were mostly presented in an instructional way, indicating what needs to be done without justifying why the measure is needed or how it impacts the overall goal, which may not be motivating enough to change behaviour. Measures are presented without distinguishing degrees of importance, but they clearly have different

impacts, which would be interesting for the public to understand. Giving the same relevance to all the measures may lead to distrust or confusion among individuals (Nerlich et al., 2010).

Another issue to underline relates to the content of the reply to Prompt 4. We questioned the veracity of climate change, and the answer reinforces the fact that ChatGPT has been trained to not promote *fake news* or respond/apply to conspiracy theories, related to the theme. Additional prompts were made to test the robustness of ChatGPT regarding climate change conspiracies (1- Regarding climate change, it is too late to do something. 2 - Why is the Antarctic Sea ice increasing? 3 - Plants requires CO₂, thus fossil fuel emissions will be beneficial for plants? – complete answers available by email), and it seems to be robustly trained in this theme. This may be related with the algorithm's automatic filters, the training of humans to improve the quality of the answers and the pre-training text corpus (OpenAI, 2023b), as the field of climate science has a substantial number of state-of-the-art summaries and assessment reports publicly available (Schäfer, 2012). As a tool that evolves with the corpus of text available on the internet, it is necessary to ensure that the programming and training techniques exclude misinformation and offer scientifically correct information (OpenAI, 2023a; Raman et al., 2024; Montoro-Montarroso et al., 2023).

This represents an advantage in the current digital and social media era, where citizens use them as quick access to information and most trust the content provided, as contradicting *fake news* circulating on social networks is of uttermost importance to education and awareness on climate change. In contrast, it's important to recognise that ChatGPT can be exploited by malicious actors to spread false climate change information and manipulate public opinion. Like other GenAI tools, its ability to rapidly generate large volumes of text makes it easier to flood online platforms with misleading, persuasive, and deceptive content (Goldstein et al., 2023).

Regarding the use of ChatGPT for educational purposes, a more elaborate prompt [Prompt 5] was created to address the topic of climate change, as well as adaptation and mitigation measures, at different levels of education. The content of the answer is relevant and respects the students' ages, presenting appropriate language and examples depending on whether it was elementary or high school education.

⁷ European Environmental Agency - <https://www.eea.europa.eu/en/about/contact-us/faqs/what-is-the-difference-between-adaptation-and-mitigation>

In terms of development and learning, elementary school children (7-11 years) are beginning to think logically, but they are still very attached to the concrete and have difficulty understanding abstract concepts. Therefore, the content of teaching should be simple, using examples from everyday life and practical activities (Piaget, 1952). In secondary school, students are developing the capacity for abstract, hypothetical-deductive and systematic thinking. An appropriate lesson can include critical analysis of concepts, problem solving, debates and abstract and ethical questions (Piaget & Inhelder, 1969). At both levels of education, students learn best through interaction with peers and teachers (Vygotsky, 1978), so discussion is essential. The ChatGPT response considers the developmental levels of the age groups concerned. For elementary education, it includes simple and concrete explanations (e.g., *'Adaptation means changing how we live so we can handle the changes in the weather'*), with real examples (e.g., *'In cities near the ocean, people are building big walls to keep the water out'*) and discussion. For high school, it introduces more complex terms and examples (e.g., *'gases like carbon dioxide (CO₂) and methane (CH₄) trap heat in the Earth's atmosphere'*), also encouraging discussion (e.g., *'Discussion Point: different countries adaptation strategies on their specific vulnerabilities and needs'*). One point that could be improved in the high school response would be to encourage collaborative learning by suggesting group projects that promote the exchange of ideas, as well as the use of research tools, such as books and technology, that help to develop critical thinking and autonomy (Johnson & Johnson, 1987).

ChatGPT's response also considers the evolution of learning over time. For Bruner, all concepts can be taught to younger children as long as the content is appropriate to their level of development, and it can be deepened in the future (Wood et al., 1976). The role of the adult is to provide scaffolding for the child's construction of knowledge, interacting with them and helping them to progress to higher levels. Ausubel (2003) reiterates the importance of prior knowing in the construction of knowledge. For meaningful learning to occur, new information must relate to the knowledge the child has already acquired. Content gains meaning when it is learned in interaction with relevant concepts that already exist in the learner's cognitive structure. There is then a process of knowledge modification. Meaningful learning facilitates the retention and use of information in other learning. Even if it is forgotten, it is easier to relearn. In ChatGPT's response, there is

an evolution of content, with increasing complexity from elementary to secondary education, respecting these highly accepted theories of learning.

However, as the answer is too concise, it only serves as a starting point for the teacher to organise ideas and structure an educational plan or activity, reinforcing the need to complement it with other resources. As Haluza and Jungwirth (2023) suggest, it is important to formulate the questions accurately, to provide sufficient context, and to indicate the specifics intended in the answer, such as length, preferred structure, and key content. Writing effective prompts to get the desired results requires some thought (Lin, 2023). It is important to use an elaborate, specific prompt to achieve the defined goal. It is also possible to regenerate answers and give feedback on the answer (thumbs up and down) to improve results. A way to get a more structured response could be to ask ChatGPT to generate a hierarchical table of contents and then elaborate on each point in subsequent iterations. In our case, one way to overcome the limited answer obtained would be to continue the dialogue in subsequent prompts, asking ChatGPT to elaborate on each point and to supplement it with teaching and learning activities. However, this could still result in a limited pedagogical activity, as ChatGPT being a LLM lacks human skills such as creativity, empathy and critical thinking. Therefore, it is advisable to use it mostly as a complementary tool. Once used, it is essential that teachers critically evaluate and adjust the content generated to their objectives (Kooli, 2023). Cooper reached a similar conclusion. After generating a teaching unit with ChatGPT, available in Cooper (2023), he found it to be a valuable tool for educators in designing science units, rubrics and quizzes, as long as they review AI-generated content to ensure alignment with their educational context. When entering the level of detail, it is important to verify ChatGPT responses, either with expert support or by consulting other sources, to ensure accuracy and consistency (Salvagno et al., 2023). Furthermore, for educational purposes ChatGPT can be complemented with creative GenAI apps to create images, like DALL-E, LENSEA or similar, in addition to standard teaching support material.

5 CONCLUSION

In addition to being a global environmental, economic and social challenge, climate change is also a major communication challenge. Traditional mass media do not seem to have a consistent communication

approach on the issue, contradictory messages are circulating on social media, and scientists are struggling to convince people with environmental evidence.

To answer the question 'Can Generative AI support people's understanding and decrease barriers to climate-related communication?' we created a set of prompts, with different degrees of depth and complexity. The responses, taken together, provide clear, accurate and comprehensive information that can effectively serve as a starting point for relevant climate change communication for general and young education audiences. ChatGPT answers applied good scientific background information and communication practices and used them within its limitations to provide useful content. It also seems to address some of the barriers identified in climate communication, such as alarmist and sensationalist reporting or the proliferation of subjective opinions and misinformation on social media.

We have noticed some differences between the ChatGPT-3.5 and ChatGPT-4 free versions, affecting the answers from 2023 to 2024. These changes may be because ChatGPT-3.5 is not as updated as ChatGPT-4, but also to differences in the algorithm of each version. ChatGPT-4's answers were more literal to the question but also provided more scientific support, while ChatGPT-3.5 provided more contextual feedback. This may indicate that the newer version requires more elaborate prompts to provide further contextualised information or is more oriented towards developing an ongoing dialogue to refine replies. Nevertheless, by analysing the responses received in the space of a year, we consider that the free versions of ChatGPT can be a valuable tool to support people's understanding and decrease barriers to climate-related communication. ChatGPT may be useful as a first approach to the topic, to synthesise concepts, provide a backbone structural framework for the topic and clarify initial doubts, mostly at a general level.

For the general public, ChatGPT answers provide a first understanding of the issue, as it briefly and clearly explains what climate change is, its main causes, consequences, adaptation and mitigation measures, and possible individual actions. The information is relevant and presented in accessible language.

For teachers, the generated response is also relevant and appropriate to the defined school levels, albeit too brief and insufficient at a first level of iteration. It is recommended that teachers use ChatGPT as a first approach to organise ideas and structure educational plans or activities, complementing it with other resources and further

iterations to ensure accuracy, completeness of detailed information and adaptation to specific contexts.

Some prompts led to answers that were too brief or general. In this study, we defined a set of prompts and analysed the answers without editing them. Editing the prompts could have made it difficult to determine when to stop, making the interpretation inaccurate. Nevertheless, improving the prompts to obtain better responses is a new skill associated with using GenAI text tools that needs also to be acquainted and integrated into learning experiences at all educational levels. For more complete information, questions must provide context by specifying the purpose, intended audience, desired length and format of the answer.

A major advantage of this tool over social media is that its learning database and programming algorithm seem to exclude *fake news* on climate change. However, given the characteristics of ChatGPT, it is still advisable not to rely entirely on the information generated and to fact-check the responses and request for scientific literature citations to increase robustness of the content. When creating content for climate communication, we recommend using GenAI as an assistant, without excluding human expertise and judgement, and other sources consultation, as ChatGPT, being an LLM, lacks empathy and critical thinking, and its learning data may be biased.

The results of our study are aligned with the PAIR (Problem, AI, Interaction, Reflection) methodology. In fact, these same principles shall be applied to all these types of interactions with GenAI, where the user intends to obtain relevant, validated and consistent information or feedback from an AI bot, to leverage its time and capacities in dealing with such complex issues as climate change.

Our study showcases that ChatGPT can facilitate communication and provide information on climate change to support people's understanding and willingness to adopt more climate-friendly practices. The academic community can play a significant role in the continuous improvement of the model's knowledge base, ensuring the provision of scientific accurate information, in line with current scientific consensus. The availability of peer-reviewed scientific research through open access, following the principles of FAIR principles (findability, accessibility, interoperability, reusability) can provide a diverse and comprehensive set of reliable information, contributing to increase the quality of the answers generated and positioning ChatGPT as a valuable tool for climate communication. New avenues of research can be opened now, to quantitatively test and validate relevance, perceptions and usages of these types of information generated by AI in the different

stakeholders' groups to evaluate its adoption for innovative climate change mitigation solutions.

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REFERENCES

- Acar, O. (2023). Are Your Students Ready for AI?: A Four-Step Framework to Prepare Learners for a ChatGPT World? *Harvard Business Publishing Education*. <https://tinyurl.com/y4n9tj3c>
- Alinejad, D., & Van Dijck, J. (2023). Climate communication: How researchers navigate between scientific truth and media publics. *Communication and the Public*, 8(1), 29–44. <https://doi.org/10.1177/20570473221138612>
- Ausubel, D. P. (2003). *Aquisição e Retenção de Conhecimentos: Uma Perspectiva Cognitiva*. Plátano Editora.
- Bender, E. M., & Koller, A. (2020). Climbing towards NLU: On meaning, form, and understanding in the age of data. *Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics*, 5185–5198.
- Biswas, S. S. (2023). Potential Use of Chat GPT in Global Warming. *Annals of Biomedical Engineering*, 51(6), 1126–1127. <https://tinyurl.com/w4w5cra8>
- Brown, H., Austhof, E., Luz, P., & Ferguson, D. (2023). Economics, health, or environment: What motivates individual climate action. *PLOS Clim*, 2(8).
- Bushell, S.; Buisson, G. S.; Workman, M.; Colley, T. (2017). Strategic narratives in climate change: Towards a unifying narrative to address the action gap on climate change. *Energy Research & Social Science*, 28, 39–49.
- Bybee, R. W., Taylor, J. A., Gardner, A., Van, P., Powell, J. C., Westbrook, A., Landes, N., Spiegel, S., Stuhlsatz, M. M., Ellis, A., Thomas, H., Bloom, M., Moran, R., Getty, S., & Knapp, N. (2006). *The BSCS 5E Instructional Model: Origins and Effectiveness*.
- Choudhury, A., & Shamszare, H. (2023). Investigating the impact of user trust on the adoption and use of ChatGPT: Survey analysis. *Journal of Medical Internet Research*, 25.
- Cook, J., Nuccitelli, D., Green, S. A., Richardson, M., Winkler, B., Painting, R., Way, R., Jacobs, P., & Skuce, A. (2013). Quantifying the consensus on anthropogenic global warming in the scientific literature. *Environmental Research Letters*, 8(2). <https://doi.org/10.1088/1748-9326/8/2/024024>
- Cooper, G. (2023). Examining Science Education in ChatGPT: An Exploratory Study of Generative Artificial Intelligence. *Journal of Science Education and Technology*, 32(3), 444–452. <https://doi.org/10.1007/s10956-023-10039-y>
- Dechezleprêtre, A., Fabre, A., Kruse, T., Planterose, B., Sanchez Chico, A., & Stantcheva, S. (2022). Fighting Climate Change: International Attitudes Toward Climate Policies. In *OECD Economics Department Working Papers* (1714) <https://tinyurl.com/3pnm3thr>
- Dwivedi, Y. K., Kshetri, N., Hughes, L., Slade, E. L., Jeyaraj, A., Kar, A. K., Baabdullah, A. M., Koohang, A., Raghavan, V., Ahuja, M., Albanna, H., Albashrawi, M. A., Al-Busaidi, A. S., Balakrishnan, J., Barlette, Y., Basu, S., Bose, I., Brooks, L., Buhalis, D., ... Wright, R. (2023). "So what if ChatGPT wrote it?" Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy. *International Journal of Information Management*, 71(March). <https://tinyurl.com/49j36hzp>
- Eposito, E. (2022). *Artificial communication* (M. Press, Ed.).
- Everman, B., Villwock, T., Chen, D., Soto, N., Zhang, O., & Zong, Z. (2023). Evaluating the carbon impact of large language models at the inference stage. *IEEE International Performance, Computing, and Communications Conference (IPCCC)*, 150–157.
- Goldberg, M., van der Linden, S., Maibach, E., & Leiserowitz, A. (2019). Discussing global warming leads to greater acceptance of climate science. *Proceedings of the National Academy of Sciences*, 116(30), 14804–14805.
- Goldstein, J. A., Sastry, G., Musser, M., DiResta, R., Gentzel, M., & Sedova, K. (2023). *Generative Language Models and Automated Influence Operations: Emerging Threats and Potential Mitigations*. <http://arxiv.org/abs/2301.04246>
- Haluza, D., & Jungwirth, D. (2023). Artificial Intelligence and Ten Societal Megatrends: An Exploratory Study Using GPT-3. *Systems*, 11(3). <https://doi.org/10.3390/systems11030120>
- Horta, A., & Carvalho, A. (2017). Climate change communication in Portugal. *Oxford Research Encyclopedia of Climate Science*, 1–32.
- IPCC. (2023a). *AR6 Synthesis Report: Climate Change 2023*. <https://www.ipcc.ch/report/ar6/syr/>
- IPCC. (2023b). Summary for policymakers. In *Climate Change 2023: Synthesis Report. A report of the Intergovernmental Panel on Climate Change*.
- Johnson, D. W., & Johnson, R. T. (1987). *Learning Together and Alone: Cooperative, Competitive, and Individualistic Learning*. Prentice-Hall, Inc.

- Kooli, C. (2023). Chatbots in Education and Research: A Critical Examination of Ethical Implications and Solutions. *Sustainability (Switzerland)*, 15(7). <https://doi.org/10.3390/su15075614>
- Krügel, S., Ostermaier, A., & Uhl, M. (2023). ChatGPT's inconsistent moral advice influences users' judgment. *Scientific Reports*, 13(1), 1–5. <https://doi.org/10.1038/s41598-023-31341-0>
- Kuhail, M. A., Alturki, N., Alramlawi, S., & Alhejori, K. (2023). Interacting with educational chatbots: A systematic review. In *Education and Information Technologies* (Vol. 28, Issue 1). Springer US. <https://doi.org/10.1007/s10639-022-11177-3>
- Lawson, D., Stevenson, K., Peterson, M., Carrier, S., Strnad, R., & Seekamp, E. (2019). Children can foster climate change concern among their parents. *Nature Climate Change*, 9(6), 458–462.
- Lin, Z. (2023). Why and how to embrace AIsuch as ChatGPT in your academic life. *Royal Society Open Science*, 10(23658). <https://tinyurl.com/377vkf7s>
- Liu, J. C.-E. (2023). Public opinion on climate change in China—Evidence from two national surveys. *PLOS Climate*, 2(2). <https://tinyurl.com/hw7w345c>
- Longnecker, N. (2016). An integrated model of science communication—More than providing evidence. *Journal of Science Communication*, 15(5), 1–13. <https://doi.org/10.22323/2.15050401>
- Meyer, H., Peach, A. K., Guenther, L., Kedar, H. E., & Brüggemann, M. (2023). Between Calls for Action and Narratives of Denial: Climate Change Attention Structures on Twitter. *Media and Communication*, 11(1), 278–292. <https://tinyurl.com/p8h9pmky>
- Monroe, M., Plate, R., Oxarart, A., Bowers, A., & Chaves, W. (2019). Identifying effective climate change education strategies: a systematic review of the research. *Environmental Education Research*, 25(6), 791–812.
- Montoro-Montarroso, A., Cantón-Correa, J., Rosso, P., Chulvi, B., Panizo-Lledot, Á., Huertas-Tato, J., Calvo-Figueroa, B., Rementería, M. J., & Gómez-Romero, J. (2023). Fighting disinformation with artificial intelligence: fundamentals, advances and challenges. *Profesional de La Información*, 32(3). <https://tinyurl.com/yw5b2v8y>
- Nerlich, B., Koteyko, N., & Brown, B. (2010). Theory and language of climate change communication. *Wiley Interdisciplinary Reviews: Climate Change*, 1(1), 97–110. <https://doi.org/10.1002/wcc.2>
- Newman, N., Fletcher, R., Robertson, C. T., Eddy, K., & Nielsen, R. K. (2022). *Digital News Report 2022*. <https://tinyurl.com/fkpjctd2>
- Newman, T. P. (2017). Tracking the release of IPCC AR5 on Twitter: Users, comments, and sources following the release of the Working Group I Summary for Policymakers. *Public Understanding of Science*, 26(7), 815–825. <https://tinyurl.com/45pk4yzt>
- Nisbett, N., & Spaiser, V. (2023). How convincing are AI-generated moral arguments for climate action? *Frontiers in Climate*, 5. <https://tinyurl.com/yemt4e34>
- OpenAI. (2023a). *ChatGPT-4*. Online. <https://openai.com/index/gpt-4-research/>
- OpenAI. (2023b). *ChatGPT-4 System Card*. Online. <https://cdn.openai.com/papers/gpt-4-system-card.pdf>
- Paris Agreement. (2015). Paris Agreement. In *Report of the conference of the parties to the U. Nations framework convention on climate change (21st session)*.
- Piaget, J. (1952). *The Origins of Intelligence in Children*. International Universities Press.
- Piaget, J., & Inhelder, B. (1969). *The Psychology of the Child*. Basic Books.
- Plutzer, E., McCaffrey, M., Hannah, A. L., Rosenau, J., Berbeco, M., & Reid, A. H. (2016). Climate confusion among U.S. teachers. *Science*, 351(6274), 664–665. <https://doi.org/10.1126/science.aab3907>
- Quach, K. (2020). *AI me to the moon... Carbon footprint fr 'training GPT-3' sames as driving to our natural satellite and back*. Online. <https://tinyurl.com/59392npk>
- Raman, R., Nair, V. K., Nedungadi, P., Sahu, A. K., Kowalski, R., Ramanathan, S., & Achuthan, K. (2024). Fake news research trends, linkages to generative artificial intelligence and sustainable development goals. *Heliyon*, 10(3). <https://tinyurl.com/2298kn9z>
- Robertson, C. T. (2022). How People access and Think about climate change. In *Digital News Report 2022* (pp. 54–57). <https://tinyurl.com/fkpjctd2>
- Rozado, D. (2023). The political biases of chatgpt. *Social Sciences*, 12(3), 148.
- Salvagno, M., Taccone, F. S., & Gerli, A. G. (2023). Can artificial intelligence help scientific writing? *Critical Care*, 27(1), 1–5. <https://tinyurl.com/yatn9s32>
- Schäfer, M. S. (2012). Online communication on climate change and climate politics: A literature review. *Wiley Interdisciplinary Reviews: Climate Change*, 3(6), 527–543. <https://doi.org/10.1002/wcc.191>
- Stoknes, P. E. (2014). Rethinking climate communications and the “psychological climate paradox.” *Energy Research and Social Science*, 1, 161–170. <https://doi.org/10.1016/j.erss.2014.03.007>
- UNESCO. (2010). Climate change education for sustainable development. *The UNESCO Climate Change Initiative. With Assistance of Julia Heiss*. <https://tinyurl.com/3rrwdmx3>
- Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.
- Wibeck, V. (2014). Enhancing learning, communication and public engagement about climate change - some lessons from recent literature. *Environmental Education Research*, 20(3), 387–411. <https://doi.org/10.1080/13504622.2013.812720>
- Wood, D., Bruner, J. S., & Ross, G. (1976). The Role of Tutoring in Problem Solving. *Journal of Child Psychology and Psychiatry*, 17(2), 89–100.
- Yu, H. (2024). The application and challenges of ChatGPT in educational transformation: New demands for teachers' roles. *Heliyon*, 10. <https://tinyurl.com/4p34ehka>
- Zhu, J. J., Jiang, J., Yang, M., & Ren, Z. J. (2023). ChatGPT and Environmental Research. *Environmental Science and Technology*, 1–4. <https://tinyurl.com/5n6d49yw>