Contribution of ChatGPT and Similar Generative Artificial Intelligence for Enhanced Climate Change Mitigation Strategies

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Abstract: The urgent acceleration of climate change necessitates the development of innovative and adaptive mitigation strategies. This study investigates how ChatGPT or Bard, an advanced language model, enhances efforts to mitigate climate change. By leveraging natural language processing and machine learning, ChatGPT facilitates improved communication, collaboration, and decision-making among stakeholders, thereby accelerating the implementation of mitigation strategies. The paper begins by examining the context of climate change, emphasizing the need for robust mitigation measures. It underscores the limitations of traditional approaches and introduces the transformative potential of integrating ChatGPT into climate action frameworks. The model's capacity to analyze extensive datasets and generate human-like text allows it to comprehend intricate climate science, distill key insights, and communicate them effectively. The study also explores ChatGPT's role in enhancing climate resilience through advanced risk assessment and adaptation planning. By analyzing climate data, the model assists in identifying vulnerable regions and developing targeted strategies for infrastructure resilience, disaster preparedness, and community engagement. The collaborative approach is essential for addressing the transboundary nature of climate change and achieving international climate goals. By harnessing the model's capabilities, stakeholders can unlock new dimensions of innovation, communication, and collaboration, paving the way for a more sustainable and resilient future.

Keywords: climate change, ChatGPT, bard, artificial intelligence, greenhouse gas, sustainable development, forecasting, decision making

1. Introduction

Addressing the urgent challenges posed by climate change necessitates innovative and effective solutions [1–4]. As the global community endeavours to attain ambitious climate goals, the significance of artificial intelligence (AI) in shaping strategies for mitigation has become increasingly apparent [5–7]. This study investigates the incorporation of ChatGPT, an advanced language model, as a transformative tool to enhance climate change mitigation strategies. Utilizing natural language processing and machine learning, ChatGPT offers a distinctive approach to enhance decision-making, promote stakeholder engagement, and facilitate the implementation of sustainable practices [8–13]. The paper explores potential applications, challenges, and ethical considerations surrounding ChatGPT in the context of climate action.

The threat of climate change to the planet's ecological balance, human societies, and economic systems is unprecedented [14–16]. Urgency in addressing this challenge has led to a reevaluation of conventional mitigation approaches [17–20]. In this quest for innovative solutions, artificial intelligence emerges as a powerful ally against climate change. Specifically, ChatGPT, a cutting-edge language model developed by OpenAI, presents a unique opportunity to revolutionize how we formulate, communicate, and implement climate change mitigation strategies [21–26]. The accelerating pace of climate change underscores the need for adaptive and agile strategies. Traditional approaches to environmental management and policy-making often struggle to keep pace with the complexity and urgency of the climate crisis. In recent years, AI technologies have shown immense potential in deciphering intricate climate data, predicting environmental trends, and optimizing resource allocation.

One primary application of ChatGPT lies in its ability to analyze vast datasets related to climate change [22, 23]. By processing and interpreting complex information, ChatGPT can contribute to more accurate climate models, enabling scientists and policymakers to make informed decisions about mitigation strategies. Effective communication is pivotal in the success of any climate change mitigation strategy. ChatGPT can create interactive and user-friendly interfaces for stakeholders, policymakers, and the general public. By providing accessible information and answering queries in real-time, ChatGPT can enhance public understanding and engagement in climate-related initiatives. ChatGPT's capacity to comprehend and generate human-like text makes it an invaluable tool for drafting policies and strategies. Its ability to analyze diverse inputs and generate coherent recommendations can streamline the policy formulation process, ensuring decisions are evidence-based and aligned with the latest scientific insights. While the integration of ChatGPT in climate change mitigation holds great promise, challenges such as bias in training data, interpretability of AI-generated recommendations, and concerns about accountability and transparency must be addressed. Ethical considerations related to privacy, security, and potential misuse of AI technologies in the context of climate change require rigorous examination. As nations strive to meet their climate goals and navigate the complexities of environmental stewardship, the integration of cutting-edge technologies like ChatGPT becomes paramount. This study contributes to the growing body of knowledge on the intersection of AI and climate change, offering insights that can inform policymakers, researchers, and technologists in harnessing the full potential of ChatGPT for enhanced climate change mitigation.

1.1. Objectives of the Study

This research aims to explore the integration of ChatGPT in climate change mitigation strategies with the following key objectives:

1) Evaluate the potential applications of ChatGPT in enhancing climate-related decision-making processes.
2) Examine the role of ChatGPT in fostering effective communication and engagement among stakeholders in the context of climate action.
3) Investigate the challenges and ethical considerations associated with the integration of ChatGPT in climate change mitigation efforts.
4) Propose recommendations for optimizing the use of ChatGPT in environmental decision-making and policy formulation.

2. Methodology

This study employs a thorough methodology, with a primary focus on literature and bibliometric analyses, to delve into the current landscape of AI applications in climate change mitigation. Furthermore, it evaluates the potential contributions stemming from the integration of ChatGPT into existing frameworks. The initial phase of this investigation encompasses an exhaustive review of current literature pertaining to climate change mitigation strategies and the utilization of AI technologies. This includes scrutinizing academic journals, conference proceedings, books, and other pertinent publications. Keyword searches are utilized to focus on particular terms related to AI, such as "artificial intelligence" and "machine learning," as well as terms associated with climate change, including "climate change" and "global warming," and those related to mitigation, such as "mitigation strategies" and "environmental sustainability." The aim of the literature review is to discern key trends, challenges, and gaps in existing knowledge, thereby laying the foundation for comprehending the current state of research at the intersection of AI and climate change mitigation. Subsequent to the comprehensive literature and bibliometric analysis, this study proposes a conceptual framework for the integration of ChatGPT into climate change mitigation strategies. This involves pinpointing specific use cases, potential benefits, and challenges associated with incorporating ChatGPT into decision-making processes related to environmental management. Fig. 1 shows the co-occurrence analysis of the keywords in literature. Fig. 2 shows the co-authorship analysis.

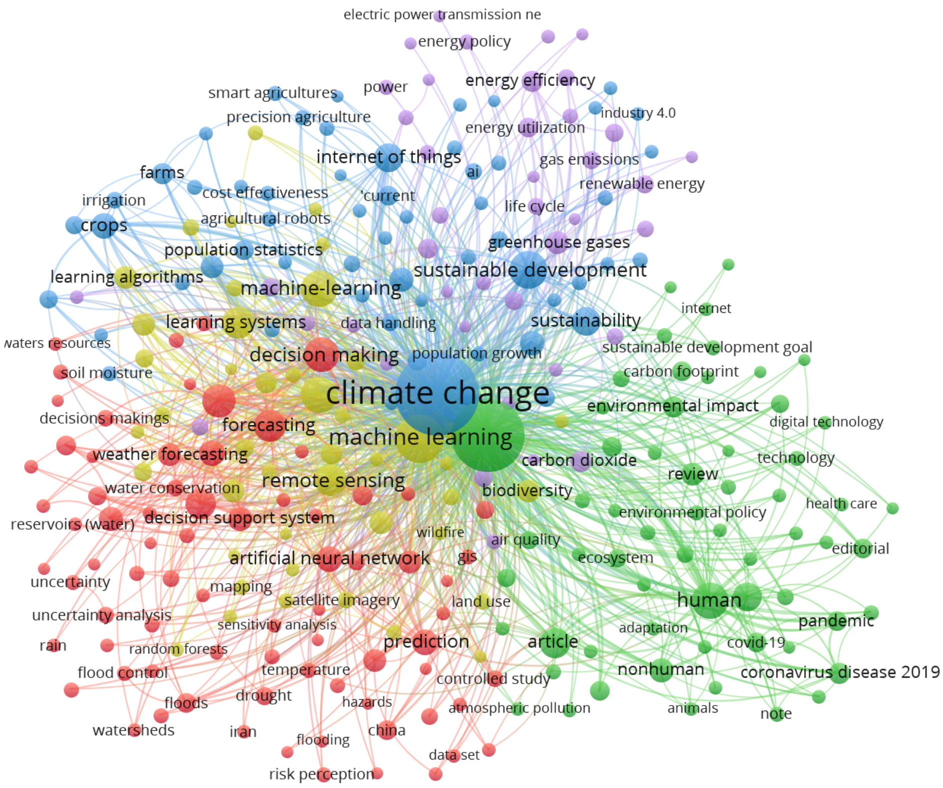

Fig. 1. Co-occurrence analysis of the keywords in literature.

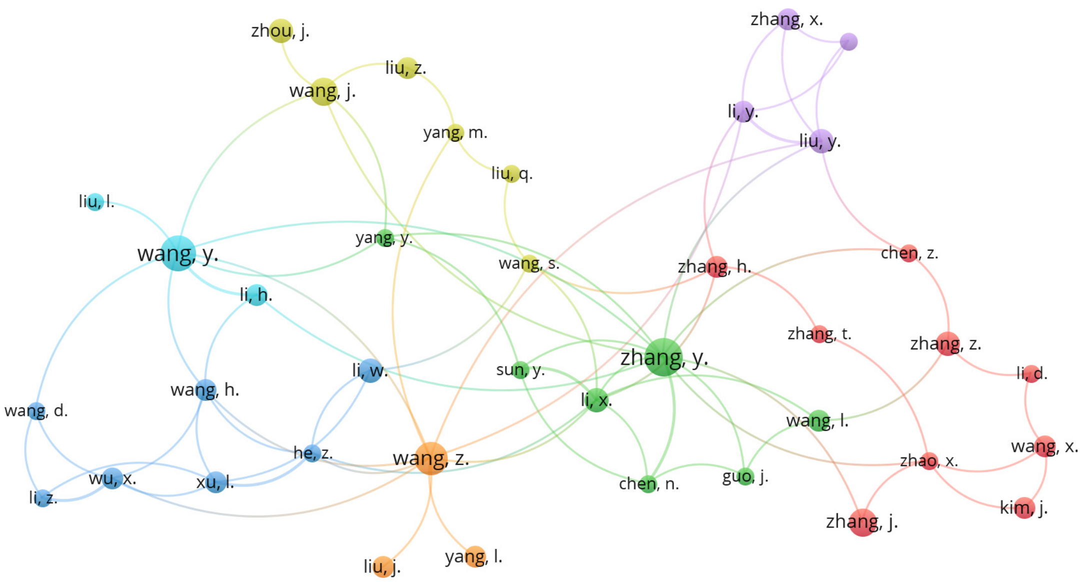

Fig. 2. Co-authorship analysis.

3. Results and Discussion

3.1. Contribution of ChatGPT or Bard for Enhanced Climate Change Mitigation Strategies

Climate change presents an existential peril to our planet, demanding urgent and inventive strategies for mitigation [15]. In recent times, artificial intelligence (AI) has emerged as a potent tool across diverse domains, with one notable application in climate change mitigation [3, 7]. OpenAI's cutting-edge language model, ChatGPT, stands poised to make substantial contributions to the enhancement of strategies combating climate change. Human activities, especially the burning of fossil fuels, deforestation, and industrial processes, have resulted in escalating greenhouse gas (GHG) emissions, culminating in global temperature increases [27–30]. The repercussions encompass extreme weather events, rising sea levels, loss of biodiversity, and disruptions to ecosystems [31–34]. Mitigating climate change demands a multifaceted approach involving GHG emission reduction, adoption of sustainable practices, and the development of pioneering technologies. AI, particularly ChatGPT, can play a pivotal role in amplifying these efforts.

3.1.1. Data analysis and decision support

ChatGPT excels in analyzing extensive datasets related to climate change, encompassing temperature records, atmospheric composition, and climate models [22, 23]. Its natural language processing capabilities empower it to extract valuable insights from scientific literature and datasets, providing comprehensive understandings of climate patterns and trends to researchers and policymakers [25, 35–39]. Additionally, ChatGPT can aid in decision support by generating detailed reports and summaries based on complex climate data, assisting policymakers in making informed decisions about targeted and effective mitigation strategies.

3.1.2. Behavioural change and public awareness

Climate change mitigation involves not only technical challenges but also changing human behavior [40–43]. ChatGPT can craft interactive and engaging educational materials to raise awareness about climate change, with chatbots powered by ChatGPT simulating conversations to provide information on sustainable practices and energy conservation [44–46]. By tailoring messages and leveraging persuasive language, ChatGPT can contribute to fostering a sense of responsibility and encouraging sustainable behaviors, facilitating a societal shift toward an environmentally conscious mindset [47–49].

3.1.3. Optimizing energy consumption

AI algorithms, including ChatGPT, can optimize energy consumption across various sectors [50–53]. ChatGPT can assist in designing and implementing smart energy management systems, facilitating communication between users and smart systems to provide insights on energy-efficient practices and encourage sustainable habits [54–57]. Moreover, ChatGPT can contribute to the development of predictive models for energy demand and supply, aiding in the integration of renewable energy sources and reducing dependency on fossil fuels.

3.1.4. Climate finance and investment strategies

Financing climate change mitigation projects is critical, and ChatGPT can analyze financial data, market trends, and risk factors to provide insights into viable climate projects [51–54]. It can assist in identifying investment opportunities in renewable energy, energy efficiency, and sustainable infrastructure [58–62]. ChatGPT can also facilitate communication between financial institutions, investors, and project developers by generating reports and summarizing investment prospects, streamlining the decision-making process and attracting more investments into sustainable projects.

3.1.5. Policy formulation and optimization

With its natural language processing capabilities, ChatGPT becomes a valuable tool for policymakers in formulating and optimizing climate change mitigation policies [63–67]. It can analyze existing policies, assess their effectiveness, and propose enhancements based on the latest scientific research and real-world data [68–72]. Additionally, ChatGPT can assist in stakeholder engagement by generating reports and summaries that communicate complex policy information in an accessible manner, fostering collaboration between governments, businesses, and civil society in implementing and adhering to policies [69, 73–77].

3.1.6. Innovation and technology development

The development of innovative technologies is crucial for ambitious climate goals, and ChatGPT and AI can contribute by analyzing scientific literature, patents, and research papers to identify emerging technologies with significant climate impact [78–82]. By assisting researchers and engineers in understanding and communicating complex scientific concepts, ChatGPT and AI can accelerate the innovation cycle and facilitate collaboration and knowledge-sharing within the scientific community for the development and deployment of cutting-edge technologies [83–86].

3.2. Leading-Edge Climate Change Mitigation Strategies

3.2.1. Carbon Capture and Storage (CCS)

ChatGPT can assist in analyzing and summarizing research findings on CCS technologies, helping policymakers and industry leaders make informed decisions about the implementation and scalability of these solutions. It can also contribute to public awareness by explaining the importance of CCS in mitigating climate change and addressing common misconceptions surrounding this technology.

3.2.2. Renewable energy integration

ChatGPT can provide insights into grid management, storage solutions, and overcoming technical challenges associated with integrating renewable energy sources into existing energy grids. It can also assist in public outreach by generating content that educates individuals about the benefits of renewable energy and dispels myths about its reliability and feasibility.

3.2.3. Circular economy practices

ChatGPT can contribute by generating content that educates businesses and consumers about the principles of a circular economy and the importance of sustainable consumption. It can also assist in the development of circular economy policies and initiatives by analyzing case studies, economic models, and best practices from around the world.

3.2.4. Nature-based solutions

ChatGPT can contribute by summarizing scientific studies on the effectiveness of different nature-based solutions, helping policymakers and land managers make informed decisions. Additionally, it can facilitate communication with local communities by generating content that explains the benefits of nature-based solutions and addresses concerns or misconceptions.

3.2.5. Electric vehicles and sustainable transportation

ChatGPT can contribute by providing information on the latest advancements in EV technology, analyzing market trends, and supporting the development of policies that incentivize sustainable transportation. It can also assist in public awareness campaigns by generating content that educates individuals about the environmental benefits of EVs and the importance of adopting sustainable transportation practices. Table 1 shows the contribution of ChatGPT to Climate Change Mitigation.

Table 1. Contribution of ChatGPT to Climate Change Mitigation

Sr No	Contribution of ChatGPT to Climate Change Mitigation	Leading-Edge Mitigation Strategies	Key Stakeholders	Challenges	Opportunities
1.	Information Dissemination:	Carbon Capture and Storage (CCS):	Government,	Misinformation,	Improved Public

	ChatGPT provides accurate climate change information, fostering awareness.	Capture and store industrial CO_2 emissions underground.	NGOs, Media	Public Apathy	Awareness, Policy Advocacy
2.	Facilitating Collaboration: ChatGPT aids global collaboration among experts, scientists, and policymakers.	Afforestation and Reforestation: Planting trees at scale for CO_2 absorption and ecosystem restoration.	Research Institutions, International Organizations	Land Use Competition, Funding Constraints	Biodiversity Conservation, Job Creation
3.	Scenario Planning: ChatGPT assists in simulating climate change scenarios for effective mitigation planning.	Renewable Energy Transition: Shift to renewable sources (solar, wind) to reduce carbon emissions.	Energy Industry, Investors, Governments	Initial Capital Investment, Infrastructure Development	Economic Growth, Energy Independence
4.	Policy Development: ChatGPT aids in crafting comprehensive climate policies.	Sustainable Agriculture Practices: Promote eco-friendly farming for emission reduction and soil health.	Agriculture Sector, Policymakers	Resistance to Change, Technological Adoption	Food Security, Soil Health Improvement
5.	Public Engagement: ChatGPT engages the public in climate discussions for behavioral change.	Climate-Resilient Infrastructure: Design infrastructure to withstand climate impacts.	Urban Planners, Engineers, Local Communities	Funding Constraints, Technological Readiness	Resilient Communities, Infrastructure Innovation
6.	Innovative Technology: ChatGPT highlights emerging climate technologies.	Circular Economy: Promote resource efficiency and waste reduction.	Tech Industry, Researchers, Policymakers	High Initial Costs, Industry Resistance	Resource Efficiency, New Markets
7.	Education and Training: ChatGPT provides climate education and training materials.	Blue Carbon Conservation: Protect coastal ecosystems for carbon sequestration.	Coastal Communities, Conservation Organizations	Coastal Development, Climate Change Denial	Ecosystem Restoration, Tourism Opportunities

3.3. Framework of ChatGPT Implementation for Enhanced Climate Change Mitigation Strategies

The Fig. 3 framework delineating the configuration and dynamics of a system concentrated on addressing climate change. The framework is composed of several interlinked components, each assigned specific roles in handling user messages, discerning mitigation strategies, evaluating feasibility, gauging impact, and furnishing recommendations.

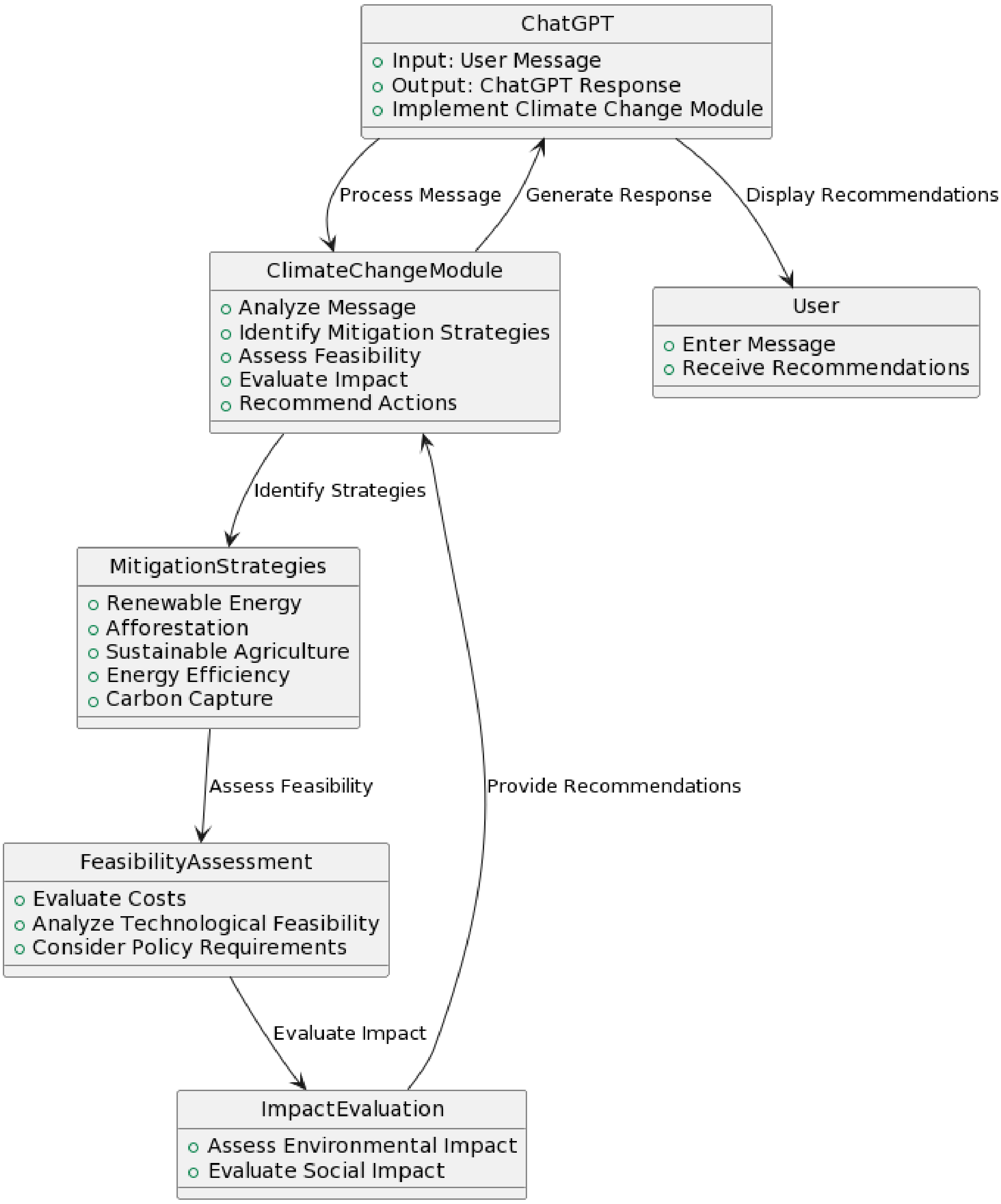

Fig. 3. Framework of ChatGPT implementation for enhanced climate change mitigation strategies.

3.3.1. ChatGPT

The ChatGPT functions as the interface for natural language processing, engaging with users. It accepts user messages and generates responses. In this instance, ChatGPT is charged with executing the Climate Change Module, interpreting user messages and crafting responses that encompass information pertinent to climate change mitigation.

3.3.2. Climate change module

This oversees functionalities associated with climate change. It dissects user messages, identifies suitable mitigation strategies, appraises their feasibility, assesses the impact of these strategies, and ultimately advises specific actions to the user. It serves as a central hub orchestrating the exchange of information among various modules.

3.3.3. Mitigation strategies

Encompassing diverse mitigation strategies to combat climate change, this lists options such as Renewable Energy, Afforestation, Sustainable Agriculture, Energy Efficiency, and Carbon Capture. These strategies represent potential recommendations to users based on their input and the system's analytical findings.

3.3.4. Feasibility assessment

This is accountable for evaluating the feasibility of identified mitigation strategies, considering factors like costs, technological viability, and policy requisites. This assessment is pivotal for determining the practicality and viability of implementing recommended strategies.

3.3.5. Impact evaluation

Focused on assessing the impact of chosen mitigation strategies, this scrutinizes both environmental and social repercussions, offering a comprehensive analysis of the outcomes tied to specific actions. This information is essential for making informed decisions about the effectiveness and desirability of proposed strategies.

3.3.6. User

The User portrays end-users interacting with the system. Users input messages, and based on system processing, they receive recommendations related to climate change mitigation. The interaction involves users supplying input, the system processing it, and the system returning recommendations to users.

3.3.7. Interactions

The arrows and connections in the diagram symbolize the flow of information and interactions between different components. For instance, ChatGPT processes user messages, activates the Climate Change Module, which, in turn, interfaces with Mitigation Strategies, Feasibility Assessment, and Impact Evaluation before delivering a response to the user.

3.4. Challenges Associated with the Use ChatGPT in Climate Change Mitigation

While ChatGPT holds immense potential for enhancing climate change mitigation efforts, it is essential to acknowledge and address challenges and ethical considerations associated with its use [87–92].

3.4.1. Bias in data

Efforts must be made to ensure that the training data is diverse and representative to mitigate biases, preventing skewed analyses or recommendations [90, 93–97].

3.4.2. Transparency and explainability

Ensuring that the outputs of ChatGPT are interpretable and verifiable is crucial to build trust among users, especially in critical decision-making processes [98–102].

3.4.3. Data privacy

Robust data protection measures are imperative to safeguard sensitive information, especially when dealing with personal data in applications related to behavioral change and public awareness [103–108].

3.4.4. Accessibility

It is essential to ensure that the benefits of AI are accessible to a wide range of users, addressing language barriers, making AI interfaces user-friendly, and considering the digital divide to prevent exacerbating existing inequalities in access to information and technology [109–115].

3.4.5. Long-term impact

The long-term impact of AI on climate change mitigation strategies should be carefully considered [116–122], including the broader environmental and societal implications, such as the carbon footprint of AI training and deployment [123–126].

4. Conclusions

Faced with unprecedented challenges posed by climate change, both researchers and policymakers have been tirelessly exploring innovative approaches to mitigate its impact and pave the way for a sustainable future. This research paper examines the integration of ChatGPT, a potent language model, as a tool to amplify climate change mitigation strategies. The urgency of climate change necessitates a multifaceted approach, and this study advocates for the synergy between human intelligence and AI to develop effective mitigation strategies. By leveraging the capabilities of ChatGPT, we can enhance our understanding of climate science, optimize resource allocation, and facilitate communication and collaboration among diverse stakeholders. A significant contribution of this research is the exploration of leading-edge mitigation strategies seamlessly integrated with ChatGPT to enhance efficacy. One such strategy involves the use of advanced climate modeling and simulation techniques. ChatGPT can assist researchers in interpreting and communicating complex climate models, enabling a broader audience, including policymakers and the general public, to comprehend the implications of various mitigation scenarios. Additionally, the model can contribute to refining existing models by processing vast datasets and identifying patterns that traditional approaches may overlook.

Renewable energy adoption emerges as another critical facet of climate change mitigation. ChatGPT can play a pivotal role in fostering public awareness and engagement by generating informative and persuasive content on the benefits of renewable energy sources. Moreover, the model can assist in developing smart grids and optimizing energy distribution networks, maximizing the efficiency of renewable energy systems. Nature-based solutions, such as afforestation and reforestation, represent innovative approaches to sequestering carbon and enhancing biodiversity. ChatGPT can aid in planning and implementing these strategies by analyzing geographical and ecological data, identifying optimal locations for tree planting, and generating educational content to raise awareness about the importance of preserving and restoring ecosystems.

Carbon capture and storage (CCS) technologies are also integral to mitigating climate change, and the integration of ChatGPT can enhance their deployment. The model can assist in identifying suitable sites for CCS facilities, optimizing capture processes, and addressing public concerns through effective communication. Additionally, ChatGPT can contribute to the development of breakthrough technologies in the field of carbon capture, accelerating progress towards scalable and cost-effective solutions. Adaptation strategies are crucial for building resilience in the face of inevitable climate impacts. ChatGPT can assist in developing adaptive measures by processing vast amounts of data related to climate risks, generating early warning systems, and providing real-time information to vulnerable communities. The model can also contribute to the formulation of adaptive policies and strategies that take into account the dynamic nature of climate change. As we face the intersection of technology and environmental stewardship, the integration of AI, exemplified by ChatGPT, offers a transformative pathway towards a more resilient and sustainable future.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

N.L.R. conducted conceptualization, methodology, formal analysis, writing original draft; S.P.C. worked for background study, writing, review & editing; and J.R. worked for writing, review & editing. All authors had approved the final version.

References

[1] Cheong, S. M., Sankaran, K., & Bastani, H. (2022). Artificial intelligence for climate change adaptation. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*. https://doi.org/10.1002/widm.1459

[2] Cowls, J., Tsamados, A., Taddeo, M., & Floridi, L. (2023). The AI gambit: leveraging artificial intelligence to combat climate change—opportunities, challenges, and recommendations. *AI and Society, 38(1)*. https://doi.org/10.1007/s00146-021-01294-x

[3] Chen, L., Chen, Z., Zhang, Y., Liu, Y., Osman, A. I., Farghali, M., Hua, J., Al-Fatesh, A., Ihara, I., Rooney, D. W., & Yap, P. S. (2023). Artificial intelligence-based solutions for climate change: a review. *In Environmental Chemistry Letters* (Vol. 21, Issue 5). https://doi.org/10.1007/s10311-023-01617-y

[4] Ballestar, M. T., Martín-Llaguno, M., & Sainz, J. (2022). An artificial intelligence analysis of climate-change influencers' marketing on Twitter. *Psychology and Marketing, 39(12)*. https://doi.org/10.1002/mar.21735

[5] Leal Filho, W., Wall, T., Rui Mucova, S. A., Nagy, G. J., Balogun, A. L., Luetz, J. M., Ng, A. W., Kovaleva, M., Safiul Azam, F. M., Alves, F., Guevara, Z., Matandirotya, N. R., Skouloudis, A., Tzachor, A., Malakar, K., & Gandhi, O. (2022). Deploying artificial intelligence for climate change adaptation. *Technological Forecasting and Social Change*, 180. https://doi.org/10.1016/j.techfore.2022.121662

[6] Gruener, S. (2022). Determinants of gullibility to misinformation: A study of climate change, COVID-19 and artificial intelligence. *Journal of Interdisciplinary Economics*. https://doi.org/10.1177/02601079221083482

[7] Nordgren, A. (2023). Artificial intelligence and climate change: Ethical issues. *Journal of Information, Communication and Ethics in Society, 21(1)*. https://doi.org/10.1108/JICES-11-2021-0106

[8] Luo, W., He, H., Liu, J., Berson, I. R., Berson, M. J., Zhou, Y., & Li, H. (2023). Aladdin's genie or pandora's box for early childhood education? Experts chat on the roles, challenges, and developments of ChatGPT. *Early Education and Development*. https://doi.org/10.1080/10409289.2023.2214181

[9] 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

[10] Rathore, Dr. B. (2023). Future of textile: Sustainable manufacturing & prediction via ChatGPT. *Eduzone : International Peer Reviewed/Refereed Academic Multidisciplinary Journal, 12(01)*. https://doi.org/10.56614/eiprmj.v12i1y23.253

[11] Budhwar, P., Chowdhury, S., Wood, G., Aguinis, H., Bamber, G. J., Beltran, J. R., Boselie, P., Lee Cooke, F., Decker, S., DeNisi, A., Dey, P. K., Guest, D., Knoblich, A. J., Malik, A., Paauwe, J., Papagiannidis, S., Patel, C., Pereira, V., Ren, S., … Varma, A. (2023). Human resource management in the age of generative artificial intelligence: Perspectives and research directions on ChatGPT. *Human Resource Management Journal, 33*(*3*). https://doi.org/10.1111/1748-8583.12524

[12] Alshahrani, A. (2023). The impact of ChatGPT on blended learning: Current trends and future research directions. *International Journal of Data and Network Science, 7(4)*. https://doi.org/10.5267/j.ijdns.2023.6.010

[13] Vrontis, D., Chaudhuri, R., & Chatterjee, S. (2023). Role of ChatGPT and skilled workers for business sustainability: Leadership motivation as the moderator. *Sustainability (Switzerland), 15(16)*. https://doi.org/10.3390/su151612196

[14] Glavovic, B. C., Smith, T. F., & White, I. (2022). The tragedy of climate change science*. Climate and Development, 14*(*9*). https://doi.org/10.1080/17565529.2021.2008855

[15] Kemp, L., Xu, C., Depledge, J., Ebi, K. L., Gibbins, G., Kohler, T. A., Rockstrom, J., Scheffer, M., Schellnhuber, H. J., Steffen, W., & Lenton, T. M. (2022). Climate Endgame: Exploring catastrophic climate change scenarios. *Proceedings of the National Academy of Sciences of the United States of America, 119(34)*.

https://doi.org/10.1073/pnas.2108146119
[16] Steg, L. (2023). Psychology of climate change. *In Annual Review of Psychology*, *74*. https://doi.org/10.1146/annurev-psych-032720-042905
[17] el Bilali, H., Bassole, I. H. N., Dambo, L., & Berjan, S. (2020). Climate change and food security. *Agriculture and Forestry, 66(3)*. https://doi.org/10.17707/AgricultForest.66.3.16
[18] Valentová, A., & Bostik, V. (2021). Climate change and human health. *Military Medical Science Letters (Vojenske Zdravotnicke Listy)*, *90*(*2*). https://doi.org/10.31482/mmsl.2021.010
[19] Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., Lacoste, A., Sankaran, K., Ross, A. S., Milojevic-Dupont, N., Jaques, N., *et al.* (2023). Tackling climate change with machine learning. *ACM Computing Surveys*, *55*(*2*). https://doi.org/10.1145/3485128
[20] Short, J. R., & Farmer, A. (2021). Cities and climate change. *Earth* (Switzerland), *2(4)*. https://doi.org/10.3390/earth2040061
[21] Gursesli, M. C., Taveekitworachai, P., Abdullah, F., Dewantoro, M. F., *et al.* (2023, October). The chronicles of ChatGPT: Generating and evaluating visual novel narratives on climate change through ChatGPT. *Proceedings of International Conference on Interactive Digital Storytelling* (pp. 181–194). Cham: Springer Nature Switzerland.
[22] Biswas, S. S. (2023). Potential use of chat gpt in global warming. *Annals of Biomedical Engineering, 51(6)*, 1126–1127.
[23] Vaghefi, S. A., Wang, Q., Muccione, V., Ni, J., Kraus, M., *et al.* (2023). *Chatclimate: Grounding Conversational AI in Climate Science*.
[24] Trajanov, D., Lazarev, G., Chitkushev, L., & Vodenska, I. (2023). Comparing the performance of ChatGPT and state-of-the-art climate NLP models on climate-related text classification tasks. *Proceedings of E3S Web of Conferences* (Vol. 436, p. 02004). EDP Sciences.
[25] Muccione, V., Stammbach, D., Ni, J., Kraus, M., *et al.* (2023). *ChatClimate: Grounding Conversational AI in Climate Science*.
[26] Agathokleous, E., Saitanis, C. J., Fang, C., & Yu, Z. (2023). Use of ChatGPT: What does it mean for biology and environmental science? *Science of the Total Environment*, *888*, 164154.
[27] Adam, A. D., & Apaydin, G. (2016). Grid connected solar photovoltaic system as a tool for green house gas emission reduction in Turkey. *Renewable and Sustainable Energy Reviews*, *53*. https://doi.org/10.1016/j.rser.2015.09.023
[28] Kealy, T. (2017). Stakeholder outcomes in a wind turbine investment; is the Irish energy policy effective in reducing GHG emissions by promoting small-scale embedded turbines in SME's? *Renewable Energy*, *101*. https://doi.org/10.1016/j.renene.2016.10.007
[29] Varma, M., Mal, H., Pahurkar, R., & Swain, R. (2020). Comparative analysis of Green House gases emission in conventional vehicles and electric vehicles. *International Journal of Advanced Science and Technology, 29(5s)*.
[30] Sukumaran, A. K. S. (2014). Carbon trading and Green House gas emission-an analysis. *Asian Journal of Scientific Research, 7(3)*. https://doi.org/10.3923/ajsr.2014.405.411
[31] Kuang, C. (2021). Analysis of Green House gases and positive impact of replacing traditional energy with clean energy. *Proceedings of E3S Web of Conferences*, *241*. https://doi.org/10.1051/e3sconf/202124102005
[32] Colling, A. v., Oliveira, L. B., Reis, M. M., da Cruz, N. T., & Hunt, J. D. (2016). Brazilian recycling potential: Energy consumption and Green House gases reduction. *Renewable and Sustainable Energy Reviews*, *59*. https://doi.org/10.1016/j.rser.2015.12.233
[33] Kannadhasan, S., & Nagarajan, N. (2022). Green house gases: Challenges, effect, and climate change.

Biomass and Bioenergy Solutions for Climate Change Mitigation and Sustainability. https://doi.org/10.4018/978-1-6684-5269-1.ch005

[34] Indira, D., & Srividya, G. (2012). Reducing the livestock related Green House gases emission. *Veterinary World, 5(4)*. https://doi.org/10.5455/vetworld.2012.244-247

[35] Rane, N., Choudhary, S., & Rane, J. (2023). Integrating ChatGPT, bard, and leading-edge generative artificial intelligence in architectural design and engineering: Applications, framework, and challenges. http://dx.doi.org/10.2139/ssrn.4645595

[36] Rane, N., Choudhary, S., & Rane, J. (2023). Integrating ChatGPT, bard, and leading-edge generative artificial intelligence in building and construction industry: Applications, framework, challenges, and future scope. http://dx.doi.org/10.2139/ssrn.4645597

[37] Moharir, K. N., Pande, C. B., Gautam, V. K., Singh, S. K., & Rane, N. L. (2023). Integration of hydrogeological data, GIS and AHP techniques applied to delineate groundwater potential zones in sandstone, limestone and shales rocks of the Damoh district, (MP) central India. *Environmental Research*, 115832. https://doi.org/10.1016/j.envres.2023.115832

[38] Rane, N., Choudhary, S., Rane, J. (2023) Enhanced product design and development using Artificial Intelligence (AI), Virtual Reality (VR), Augmented Reality (AR), 4D/5D/6D Printing, Internet of Things (IoT), and blockchain: A review. http://dx.doi.org/10.2139/ssrn.4644059

[39] Rane, N., Lopes, S., Raval, A., Rumao, D., & Thakur, M. P. (2017). Study of effects of labour productivity on construction projects. *International Journal of Engineering Sciences and Research Technology, 6(6)*, 15–20.

[40] DEDE. (2012). Alternative energy development plan (2012–2021). *International Journal of Renewable Energy, 7(1)*.

[41] Ling, S. K., Hamidi, A. A., & Suffian, B. Y. (2014). Study on municipal solid waste Management in malaysia: Case study in Kuching, Miri and Sibu. *Advances in Environmental Biology, 8(15)*. https://doi.org/10.47609/jras2017v6i2p2

[42] KAUR, P. (2022). Explained: How to save our environment for our future generations through sustainable food systems? *Annals of Ayurvedic Medicine*, 0. https://doi.org/10.5455/aam.103794

[43] Ojo, G. O., & Bowen, D. M. (2014). Environmental and economic analysis of solid waste management alternatives for Lagos Municipality, Nigeria. *Journal of Sustainable Development in Africa, 16(1).*

[44] Patrianti, T., Bajari, A., Agustin, H., & Bakti, I. (2020). Climate change communication on mitigation policy and its challenges towards Sustainable Development Goals (SDGs). *International Journal of Advanced Science and Technology, 29(6)*.

[45] Islam, M. M., Siffat, S. A., Ahmad, I., Liaquat, M., & Khan, S. A. (2021). Adaptive nonlinear control of unified model of fuel cell, battery, ultracapacitor and induction motor based hybrid electric vehicles. *IEEE Access*, *9*. https://doi.org/10.1109/ACCESS.2021.3072478

[46] Madumere, N. (2017). Public enlightenment and participation – A major contribution in mitigating climate change. *International Journal of Sustainable Built Environment, 6(1)*. https://doi.org/10.1016/j.ijsbe.2016.10.003

[47] Liew, K. M., Sojobi, A. O., & Zhang, L. W. (2017). Green concrete: Prospects and challenges. *Construction and Building Materials*, *156.* https://doi.org/10.1016/j.conbuildmat.2017.09.008

[48] Jiang, B., Sun, Z., & Liu, M. (2010). China's energy development strategy under the low-carbon economy. *Energy, 35(11)*. https://doi.org/10.1016/j.energy.2009.12.040

[49] Kawamoto, K., Okuda, T., & Morisugi, M. (2011). Structural analysis of regional factors with social capital affect low carbon travel behavior. *Studies in Regional Science*, *41(1)*. https://doi.org/10.2457/srs.41.161

[50] Khan, U. (2023). Revolutionizing personalized protein energy malnutrition treatment: harnessing the

power of Chat GPT. *Annals of Biomedical Engineering*, 1–3.
[51] Wu, T., He, S., Liu, J., Sun, S., Liu, K., Han, Q. L., & Tang, Y. (2023). A brief overview of ChatGPT: The history, status quo and potential future development. *IEEE/CAA Journal of Automatica Sinica*, *10*(*5*), 1122-1136.
[52] Beldavs, V., Egbo, D. A. M., Odari, B. V., Samba, E. N., *et al.* (2023). ChatGPT and other AI tools to accelerate development at the community level in Sub-Saharan Africa. *Book of Abstracts* (p. 56).
[53] Adesso, G. (2023). Towards the ultimate brain: Exploring scientific discovery with ChatGPT AI. *AI Magazine*, *44*(*3*), 328-342.
[54] Roumeliotis, K. I., & Tselikas, N. D. (2023). ChatGPT and Open-AI models: A preliminary review. *Future Internet, 15*(6), 192.
[55] Gamage, G., Kahawala, S., Mills, N., De Silva, D., Manic, M., Alahakoon, D., & Jennings, A. (June 2023). Augmenting industrial Chatbots in energy systems using ChatGPT generative AI. *Proceedings of 2023 IEEE 32nd International Symposium on Industrial Electronics (ISIE)* (pp. 1-6). IEEE.
[56] Guo, S., Wang, Y., Li, S., & Saeed, N. (2023). Semantic communications with ordered importance using ChatGPT. arXiv preprint arXiv:2302.07142.
[57] Liesenfeld, A., Lopez, A., & Dingemanse, M. (July 2023). Opening up ChatGPT: Tracking openness, transparency, and accountability in instruction-tuned text generators. *Proceedings of the 5th International Conference on Conversational User Interfaces* (pp. 1-6).
[58] Rane, N., Choudhary, S., & Rane, J. (2023). Integrating Building Information Modelling (BIM) with ChatGPT, Bard, and similar generative artificial intelligence in the architecture, engineering, and construction industry: Applications, a novel framework, challenges, and future scope. http://dx.doi.org/10.2139/ssrn.4645601
[59] Rane, N., Choudhary, S., & Rane, J. (2023). Artificial Intelligence (AI) and Internet of Things (IoT) - based sensors for monitoring and controlling in architecture, engineering, and construction: Applications, challenges, and opportunities. http://dx.doi.org/10.2139/ssrn.4642197
[60] Gautam, V. K., Pande, C. B., Moharir, K. N., Varade, A. M., Rane, N. L., Egbueri, J. C., & Alshehri, F. (2023). Prediction of sodium hazard of irrigation purpose using artificial neural network modelling. *Sustainability, 15*(*9*), 7593. https://doi.org/10.3390/su15097593
[61] Rane, N., Choudhary, S., & Rane, J. (2023). Leading-edge technologies for architectural design: A comprehensive review. http://dx.doi.org/10.2139/ssrn.4637891
[62] Rane, N., Choudhary, S., & Rane, J. (2023). Blockchain and Artificial Intelligence (AI) integration for revolutionizing security and transparency in finance. http://dx.doi.org/10.2139/ssrn.4644253
[63] Sahu, M., Chattopadhyay, B., Das, R., & Chaturvedi, S. (2023). Measuring impact of climate change on indigenous health in the background of multiple disadvantages: A scoping review for equitable public health policy formulation. *Journal of Prevention, 44*(*4*). https://doi.org/10.1007/s10935-022-00718-8
[64] Kıprızlı, G., & Köstem, S. (2022). Understanding the BRICS framing of climate change: The role of collective identity formation. *International Journal, 77*(*2*). https://doi.org/10.1177/00207020221135300
[65] Jha, C. K., & Gupta, V. (2021). Farmer's perception and factors determining the adaptation decisions to cope with climate change: An evidence from rural India. *Environmental and Sustainability Indicators, 10*. https://doi.org/10.1016/j.indic.2021.100112
[66] Afuye, G. A., Kalumba, A. M., & Orimoloye, I. R. (2021). Characterisation of vegetation response to climate change: A review. *Sustainability (Switzerland), 13*(*13*). https://doi.org/10.3390/su13137265
[67] Williams, D. S., Rosendo, S., Sadasing, O., & Celliers, L. (2020). Identifying local governance capacity needs for implementing climate change adaptation in Mauritius. *Climate Policy*, *20*(*5*). https://doi.org/10.1080/14693062.2020.1745743

[68] Rhodes, E. R., Jalloh, A., & Diouf, A. (2014). Review of research and policies for climate change adaptation in the agriculture sector in West Africa. Coraf, May.

[69] Lesnikowski, A., Biesbroek, R., Ford, J. D., & Berrang-Ford, L. (2021). Policy implementation styles and local governments: the case of climate change adaptation. *Environmental Politics, 30*(*5*). https://doi.org/10.1080/09644016.2020.1814045

[70] Mardiastuti, A. (2020). Gaps in science and policy formulation of climate change: Perspective from university. *IOP Conference Series: Earth and Environmental Science, 487*(*1*). https://doi.org/10.1088/1755-1315/487/1/012003

[71] Chatanga, R. (2023). New Public Governance theory: A framework for Lesotho policymakers to enhance community participation during climate change policy formulation and implementation. *Administratio Publica, 31*(*2*).

[72] Ampaire, E. L., Jassogne, L., Providence, H., Acosta, M., Twyman, J., Winowiecki, L., & van Asten, P. (2017). Institutional challenges to climate change adaptation: A case study on policy action gaps in Uganda. *Environmental Science and Policy, 75*. https://doi.org/10.1016/j.envsci.2017.05.013

[73] Rane, N., Choudhary, S., & Rane, J. (2023). Explainable Artificial Intelligence (XAI) approaches for transparency and accountability in financial decision-making. http://dx.doi.org/10.2139/ssrn.4640316

[74] Rane, N., Choudhary, S., & Rane, J. (2023). Enhancing lithium-ion battery performance with emerging electrolyte materials for sustainable energy storage solutions: a comprehensive review and prospects. http://dx.doi.org/10.2139/ssrn.4643648

[75] Rane, N. L., Achari, A., Saha, A., Poddar, I., Rane, J., Pande, C. B., & Roy, R. (2023). An integrated GIS, MIF, and TOPSIS approach for appraising electric vehicle charging station suitability zones in Mumbai, India. *Sustainable Cities and Society, 104717.* https://doi.org/10.1016/j.scs.2023.104717

[76] Rane, N., Choudhary, S., & Rane, J. (2023). Sustainable tourism development using leading-edge Artificial Intelligence (AI), Blockchain, Internet of Things (IoT), Augmented Reality (AR) and Virtual Reality (VR) technologies. http://dx.doi.org/10.2139/ssrn.4642605

[77] Rane, N., Choudhary, S., & Rane, J. (2023). Leading-edge Artificial Intelligence (AI) and Internet of Things (IoT) technologies for enhanced geotechnical site characterization. http://dx.doi.org/10.2139/ssrn.4640926

[78] Ray, P. P. (2023). ChatGPT: A comprehensive review on background, applications, key challenges, bias, ethics, limitations and future scope. *Internet of Things and Cyber-Physical Systems, 3*. https://doi.org/10.1016/j.iotcps.2023.04.003

[79] Sardana, D., Fagan, T. R., & Wright, J. T. (2023). ChatGPT: A disruptive innovation or disrupting innovation in academia? *Journal of the American Dental Association, 154*(*5*). https://doi.org/10.1016/j.adaj.2023.02.008

[80] Fütterer, T., Fischer, C., Alekseeva, A., Chen, X., Tate, T., Warschauer, M., & Gerjets, P. (2023). ChatGPT in education: global reactions to AI innovations. *Scientific Reports, 13*(*1*). https://doi.org/10.1038/s41598-023-42227-6

[81] Dai, Y., Liu, A., & Lim, C. P. (2023). Reconceptualizing ChatGPT and generative AI as a student-driven innovation in higher education. *Procedia CIRP, 119*. https://doi.org/10.1016/j.procir.2023.05.002

[82] Agapiou, A., & Lysandrou, V. (2023). Interacting with the Artificial Intelligence (AI) language model ChatGPT: A synopsis of earth observation and remote sensing in archaeology. *Heritage, 6*(*5*). https://doi.org/10.3390/heritage6050214

[83] Raman, R., Mandal, S., Das, P., Kaur, T., JP, S., & Nedungadi, P. (2023). University students as early adopters of ChatGPT: Innovation Diffusion Study. Research Square.

[84] Naumova, E. N. (2023). A mistake-find exercise: a teacher's tool to engage with information innovations,

ChatGPT, and their analogs. *Journal of Public Health Policy, 44*(*2*). https://doi.org/10.1057/s41271-023-00400-1

[85] Shaji, *et al.* (2023). Partners Universal International Innovation Journal (PUIIJ) A review of ChatGPT AI's impact on several business sectors. *Partners Universal International Innovation Journal (PUIIJ), 01*(*01*).

[86] Ratten, V., & Jones, P. (2023). Generative artificial intelligence (ChatGPT): Implications for management educators. *International Journal of Management Education, 21*(*3*). https://doi.org/10.1016/j.ijme.2023.100857

[87] Shoufan, A. (2023). Exploring students' perceptions of ChatGPT: Thematic analysis and follow-up survey. *IEEE Access, 11*. https://doi.org/10.1109/ACCESS.2023.3268224

[88] Fui-Hoon Nah, F., Zheng, R., Cai, J., Siau, K., & Chen, L. (2023). Generative AI and ChatGPT: Applications, challenges, and AI-human collaboration. *Journal of Information Technology Case and Application Research*, *25(3)*. https://doi.org/10.1080/15228053.2023.2233814

[89] Alshurafat, H. (2023). The usefulness and challenges of chatbots for accounting professionals: Application on ChatGPT. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4345921

[90] Liu, J., Wang, C., & Liu, S. (2023). Utility of ChatGPT in clinical practice. *Journal of Medical Internet Research, 25*. https://doi.org/10.2196/48568

[91] Chinonso, O. E., Theresa, A. M.-E., & Aduke, T. C. (2023). ChatGPT for teaching, learning and research: Prospects and challenges. *Global Academic Journal of Humanities and Social Sciences*, *5*(*02*). https://doi.org/10.36348/gajhss.2023.v05i02.001

[92] Parray, A. A., Inam, Z. M., Ramonfaur, D., Haider, S. S., Mistry, S. K., & Pandya, A. K. (2023). ChatGPT and global public health: Applications, challenges, ethical considerations and mitigation strategies. *Global Transitions, 5.* https://doi.org/10.1016/j.glt.2023.05.001

[93] Rane, N., Choudhary, S., & Rane, J. (2023). Metaverse as a cutting-edge platform for attaining Sustainable Development Goals (SDGs). http://dx.doi.org/10.2139/ssrn.4644035

[94] Rane, N., Choudhary, S., & Rane, J. (2023). Leading-edge wearable technologies in enhancing personalized safety on construction sites: a review. http://dx.doi.org/10.2139/ssrn.4641480

[95] RRane, N., Choudhary, S., & Rane, J. (2023). Hyper-personalization for enhancing customer loyalty and satisfaction in Customer Relationship Management (CRM) systems. http://dx.doi.org/10.2139/ssrn.4641044

[96] Rane, N., Choudhary, S., & Rane, J. (2023). Metaverse marketing strategies: Enhancing customer experience and analysing consumer behaviour through leading-edge metaverse technologies, platforms, and models. http://dx.doi.org/10.2139/ssrn.4624199

[97] Rane, N., Choudhary, S., & Rane, J. (2023). Enhancing thermal comfort through leading-edge design, monitoring, and optimization technologies: A review. http://dx.doi.org/10.2139/ssrn.4642529

[98] Cotton, D. R. E., Cotton, P. A., & Shipway, J. R. (2023). Chatting and cheating: Ensuring academic integrity in the era of ChatGPT. *Innovations in Education and Teaching International.* https://doi.org/10.1080/14703297.2023.2190148

[99] Hassani, H., & Silva, E. S. (2023). The role of ChatGPT in data science: How AI-assisted conversational interfaces are revolutionizing the field. *Big Data and Cognitive Computing, 7*(*2*). https://doi.org/10.3390/bdcc7020062

[100] Oxford Analytica. (2023). ChatGPT deepens corporate cybersecurity challenge. *Emerald Expert Briefings*, oxan-es(oxan-es).

[101] Dönmez, I., Idil, S., & Gulen, S. (2023). ChatGPT: Challenges and opportunities. *Technology, Engineering, Mathematics and Art Education, 6*(*2*).

[102] Jain, V., Rai, H., P., & Mogaji, E. (2023). The prospects and challenges of ChatGPT on marketing

research and practices. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4398033

[103] Ferrara, E. (2023). Social bot detection in the age of ChatGPT: Challenges and opportunities. *First Monday, 28*(*6*). https://doi.org/10.5210/fm.v28i6.13185

[104] Cheng, H. W. (2023). Challenges and limitations of ChatGPT and artificial intelligence for scientific research: A perspective from organic materials. *AI (Switzerland), 4*(*2*). https://doi.org/10.3390/ai4020021

[105] Hu, X., Tian, Y., Nagato, K., Nakao, M., & Liu, A. (2023). Opportunities and challenges of ChatGPT for design knowledge management. *Procedia CIRP, 119*. https://doi.org/10.1016/j.procir.2023.05.001

[106] Liebrenz, M., Schleifer, R., Buadze, A., Bhugra, D., & Smith, A. (2023). Generating scholarly content with ChatGPT: ethical challenges for medical publishing. *The Lancet Digital Health, 5*(*3*). https://doi.org/10.1016/S2589-7500(23)00019-5

[107] Chowdhury, N. A. (2023). A brief review of ChatGPT: Limitations, challenges and ethical-social implications. ResearchGate.

[108] Donmez, İ., Idin, S., & Gulen, S. (2023). Conducting academic research with the AI Interface ChatGPT: Challenges and opportunities. *Journal of STEAM Education, 6*(*2*).

[109] R Rane, N., Choudhary, S., & Rane, J. (2023). Education 4.0 and 5.0: Integrating artificial intelligence (AI) for personalized and adaptive learning. http://dx.doi.org/10.2139/ssrn.4638365

[110] Rane, N., Choudhary, S., & Rane, J. (2023). Metaverse for enhancing customer loyalty: Effective strategies to improve customer relationship, service, engagement, satisfaction, and experience. http://dx.doi.org/10.2139/ssrn.4624197

[111] Patil, D. R., Rane, N. L., (2023) Customer experience and satisfaction: importance of customer reviews and customer value on buying preference. *International Research Journal of Modernization in Engineering Technology and Science, 5*(*3*), 3437-3447. https://www.doi.org/10.56726/IRJMETS36460

[112] Rane, N., Choudhary, S., & Rane, J. (2023). Leading-edge Artificial Intelligence (AI), Machine Learning (ML), Blockchain, and Internet of Things (IoT) technologies for enhanced wastewater treatment systems. http://dx.doi.org/10.2139/ssrn.4641557

[113] Rane, N. L., & Attarde, P. M. (2016). Application of value engineering in commercial building projects. *International Journal of Latest Trends in Engineering and Technology*, *6*(*3*), 286-291.

[114] Su, J., & Yang, W. (2023). Unlocking the power of ChatGPT: A framework for applying generative AI in education. *ECNU Review of Education*, *6*(*3*). https://doi.org/10.1177/20965311231168423

[115] Sohail, S. S., Farhat, F., Himeur, Y., Nadeem, M., Madsen, D. Ø., Singh, Y., Atalla, S., & Mansoor, W. (2023). Decoding ChatGPT: A taxonomy of existing research, current challenges, and possible future directions. *Journal of King Saud University - Computer and Information Sciences, 35*(*8*). https://doi.org/10.1016/j.jksuci.2023.101675

[116] Wang, X., Sanders, H. M., Liu, Y., Seang, K., Tran, B. X., Atanasov, A. G., Qiu, Y., Tang, S., Car, J., Wang, Y. X., Wong, T. Y., Tham, Y. C., & Chung, K. C. (2023). ChatGPT: promise and challenges for deployment in low- and middle-income countries. *The Lancet Regional Health - Western Pacific, 41*. https://doi.org/10.1016/j.lanwpc.2023.100905

[117] Xames, M. D., & Shefa, J. (2023). ChatGPT for research and publication: Opportunities and challenges. *Journal of Applied Learning and Teaching, 6*(*1*). https://doi.org/10.37074/jalt.2023.6.1.20

[118] Islam, I., Islam, M. N., *et al.* (2023). Opportunities and challenges of ChatGPT in Academia: A conceptual analysis. *Authorea Preprints*.

[119] Trust, T., Whalen, J., & Mouza, C. (2023). Editorial: ChatGPT: Challenges, opportunities, and implications for teacher education. *Contemporary Issues in Technology and Teacher Education*, *23*(*1*).

[120] Alafnan, M. A., Dishari, S., Jovic, M., & Lomidze, K. (2023). ChatGPT as an educational tool:

Opportunities, challenges, and recommendations for communication, business writing, and composition courses. *Journal of Artificial Intelligence and Technology, 3*(*2*). https://doi.org/10.37965/jait.2023.0184

[121] Rasul, T., Nair, S., Kalendra, D., Robin, M., Santini, F. de O., Ladeira, W. J., Sun, M., Day, I., Rather, R. A., & Heathcote, L. (2023). The role of ChatGPT in higher education: Benefits, challenges, and future research directions. *Journal of Applied Learning and Teaching, 6*(*1*). https://doi.org/10.37074/jalt.2023.6.1.29

[122] Cingillioglu, I. (2023). Detecting AI-generated essays: The ChatGPT challenge. *International Journal of Information and Learning Technology, 40*(*3*). https://doi.org/10.1108/IJILT-03-2023-0043

[123] Deng, J., & Lin, Y. (2022). Frontiers in computing and intelligent systems the benefits and challenges of ChatGPT: An overview. *Frontiers in Computing and Intelligent Systems, 2*(*2*).

[124] Sánchez-Ruiz, L. M., Moll-López, S., Nuñez-Pérez, A., Moraño-Fernández, J. A., & Vega-Fleitas, E. (2023). ChatGPT challenges blended learning methodologies in engineering education: A case study in mathematics. *Applied Sciences (Switzerland), 13*(*10*). https://doi.org/10.3390/app13106039

[125] Deng, J., & Lin, Y. (2023). The Benefits and challenges of ChatGPT: An overview. *Frontiers in Computing and Intelligent Systems, 2*(*2*). https://doi.org/10.54097/fcis.v2i2.4465

[126] Gill, S. S., & Kaur, R. (2023). ChatGPT: Vision and challenges. *Internet of Things and Cyber-Physical Systems, 3*. https://doi.org/10.1016/j.iotcps.2023.05.004