



ChatGPT, a friend or a foe?

Integration of artificial intelligence-enabled chatbots in academic research

By **Mudasir A. Yattoo and Faiza Habib**

On many websites, a chatbot in a window corner will pop up asking if the user needs assistance. Chatbots are intelligent conversational software programs designed to mirror human communication and are widely used to provide automated online support to customers and users. They utilize artificial intelligence (AI) methods and algorithms, and their versatility has led to their wide adoption by varied industry players to aid customers. Early chatbots such as ELIZA and PARRY were mostly developed to mimic humans to make the user believe that they are interacting with another person. While a chatbot on a browser window corner may appear technologically impressive, they are just the basic forms of chatbots.

Chatbots have come a long way and developers powered by huge amounts of data are employing deep learning, natural language processing, and machine learning algorithms to build advanced chatbots.¹ One example of such a cutting-edge chatbot is ChatGPT (Chat Generative Pre-Trained Transformer). Based on natural language processing, it has taken the world by storm—it was released in November 2022 by OpenAI and it took only five days to reach 1 million users and crossed 100 million users within two months after its release. In contrast, it took more than two months for Instagram to have the first million signups and TikTok took about nine months after its global launch to reach 100 million users.^{1–3} ChatGPT represents the fastest

adoption of any consumer app ever to date.

While technological innovations are generally forward-looking, AI has long been a source of contention between its champions and critics. Applications of AI include personalized shopping and learning, AI-powered assistants, fraud prevention, smart content creation, voice assistants, and autonomous vehicles, for example. Notwithstanding the applications of AI, some major criticisms of the technology are its (mis)use by authoritarian governments, algorithm bias, and the existential threat posed by superintelligent AI wherein AI may be able to improve itself to the point that we humans could not control it. It, therefore, is no surprise that ChatGPT in its short span has unleashed hopes among champions of AI as well as panic among critics.

The proposed use of ChatGPT in academia—including writing research grants, discussing newer research directions, and writing research manuscripts—has rightly caused panic, to the point that publishers such as the American Association for the Advancement of Science (AAAS), which publishes the highly reputable journal *Science*, banned listing ChatGPT as an author and having its text appear in scientific scholarly papers.^{4,5} Other major publishers such as Springer Nature* and Elsevier have also banned listing ChatGPT as an author in their papers, but both publishers allow its use ostensibly to improve the legibility and language of the research article.⁶

Despite the slightly different approaches taken by the top three publishers, a consensus on containing the bot seems to be arriving. ChatGPT has already appeared as a co-author^{4–6} in many papers but banning its listing as an author by some major publishers appears to be a reasonable approach because ChatGPT cannot agree to be a co-author and, most importantly, cannot be held accountable for work published. Or is there a way of changing the ChatGPT co-author agreement and accountability liability on the paper's corresponding author? Maybe yes or maybe no, only time will tell.

A gray area, however, appears to be its use and assistance in writing research articles. AAAS has banned this outright while Springer Nature and Elsevier appear to be okay with its use. Other publishers including Taylor & Francis are reviewing their policies and therefore have yet to decide. Some publishers including the American Chemical Society have already published content produced by ChatGPT,⁷ and there is sound logic in allowing its use wherein nonnative English speakers could use AI-powered programs such as ChatGPT to improve the language and coherence in their research articles. Language has long been an issue, rather a hindrance, for scientific publications, and ChatGPT could very well level the playing field when it comes to language to strengthen the growth of science through publications.

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*Springer Nature is a publishing alliance of the Materials Research Society.

A major issue, however, is the promotion of “junk science” for which ChatGPT could inadvertently play a role. It is a known fact that there are outright fraudulent and predatory publishers⁸ only interested in making a profit and authors publishing in such journals are also mostly concerned with increasing their publication and citation indices. Such a combination is deeply worrying and ChatGPT has the potential to catalyze it to great lengths. While a fight against predatory publishers will continue and “junk science” will keep appearing, a possible remedy for genuine publishers may very well be allowing the use of ChatGPT in manuscript writing with a clear mention including details of ChatGPT usage in the Acknowledgment section of the paper—at least until the time we have counter technologies to detect ChatGPT- and other bot-produced work.

An equally important problem we see for ChatGPT-assisted manuscript writing is the referencing and crediting of the original authors for the work cited. The negative impact of secondary and tertiary citations including oversimplification and misinterpretation of original work has already been identified as a problem in scientific research. Now it appears that ChatGPT could further increase such incidences because the content it produces—even though it could include citations to previously published work—would still need thorough work by the scientists to improve the referencing. The worst-case scenario that we observe periodically is an entire list of fake references. A few examples of manuscript introductions with references produced by ChatGPT are in the Appendix. When compared to the corresponding manuscript introductions published by us in related research areas,^{9–14} fake referencing by ChatGPT is very vivid. More importantly, however, the published original article introductions are denser, more detailed, and richly referenced than the demonstrations by the bot. Irrespective of these shortfalls it is undeniable that ChatGPT would be a useful tool for scientific paper and grant writing, but whether

it would impact the role of literature survey and possibly negatively impact the knowledge base of early-career scientists is still an open question.

Above all, the most serious concern with bots such as ChatGPT is algorithm bias, for instance, in the context of climate change. This is compounded by the fake referencing capability of ChatGPT. A climate change denier would be able to write an article with apparently rich (fake) referencing to sway readers into believing that there is widely published scientific literature debunking climate change. In a field such as materials science where one of the research focus areas is technologies to mitigate climate change, this should be identified as a cause of concern. While arguing for and banning AI-powered innovations such as ChatGPT would be a knee-jerk reaction, a much more circumspect approach—including working alongside players such as OpenAI and promoting open-source data science—may be advantageous. This probably also reinforces the argument for close collaboration between science and policymaking which could involve lobbying for legally binding laws on players such as OpenAI to keep a regular check on the content produced by their technologies, with a particular eye on the content relating to existential challenges such as climate change.

It is very early to make proclamations on the uproar caused by ChatGPT in the past months, but we believe the hype will die soon. This probably is the nature of human civilization that we “overreact” and for good reasons—the fear of new things, after all, is embedded in us for evolutionary reasons. While it is difficult to say with a high degree of confidence, ChatGPT may very well turn out to be the Microsoft Excel of our times, so don’t be surprised if we all end up integrating it into our daily lives, including scientific research and writing.

References

1. S. Mollman, “ChatGPT Gained 1 Million Users in Under a Week. Here’s Why the AI Chatbot Is Primed to Disrupt Search as We Know It,”

yahoo!finance (2022). <https://finance.yahoo.com/news/chatgpt-gained-1-million-followers-224523258.html>

2. Tech Desk, “ChatGPT Hit 1 Million Users in 5 Days: Here’s How Long It Took Others to Reach That Milestone,” *The Indian Express* (2023). <https://indianexpress.com/article/technology/artificial-intelligence/chatgpt-hit-1-million-users-5-days-vs-netflix-facebook-instagram-spotify-mark-8394119>
3. D. Milmo, “ChatGPT Reaches 100 Million Users Two Months After Launch,” *The Guardian* (2023). <https://www.theguardian.com/technology/2023/feb/02/chatgpt-100-million-users-open-ai-fastest-growing-app>
4. ChatGPT Generative Pre-trained Transformer and A. Zhavoronkov, *Oncoscience* **9**, 82 (2022). <https://doi.org/10.18632/oncoscience.571>
5. T.H. Kung, M. Cheatham, ChatGPT, A. Medenilla, C. Sillos, L. De Leon, C. Elepaño, M. Madiaga, R. Aggabao, G. Diaz-Candido, J. Maningo, V. Tseng, “Performance of ChatGPT on USMLE: Potential for AI-Assisted Medical Education Using Large Language Models,” Preprint, medRxiv (2022). <https://doi.org/10.1101/2022.12.19.22283643>
6. S. O’Connor, ChatGPT, *Nurse Educ. Pract.* **66**, 103537 (2023)
7. A.R. Kirmani, *ACS Energy Lett.* **8**, 574 (2023)
8. J. Beall, Beall’s List of Potential Predatory Journals and Publishers (2021)
9. F. Habib, D.A. Tocher, N.J. Press, C.J. Carmalt, *Microporous Mesoporous Mater.* **308**, 110548 (2020). <https://doi.org/10.1016/j.micromeso.2020.110548>
10. F. Habib, D.A. Tocher, C.J. Carmalt, *Mater. Today Proc.* **56**, 3766 (2022). <https://doi.org/10.1016/j.matpr.2022.01.018>
11. M.A. Yattoo, S.S. Kawale, S.J. Skinner, “Perovskite and Layered Oxide Materials for Intermediate Temperature Solid Oxide Fuel Cells,” in *Intermediate Temperature Solid Oxide Fuel Cells*, ed. by G. Kaur (Elsevier, Amsterdam, 2020), chap. 9, pp. 315–346. <https://doi.org/10.1016/B978-0-12-817445-6.00010-7>
12. M.A. Yattoo, Z. Du, Z. Yang, H. Zhao, S.J. Skinner, *Crystals* (Basel) **10**(6), 428 (2020). <https://doi.org/10.3390/cryst10060428>
13. J.P. Baboo, M.A. Yattoo, M. Dent, E. Hojaji Najafabadi, C. Lekakou, R. Slade, S.J. Hinder, J.F. Watts, *Energies* (Basel) **15**, 2332 (2022). <https://doi.org/10.3390/en15072332>
14. J.P. Baboo, E. Jakubczyk, M.A. Yattoo, M. Phillips, S. Grabe, M. Dent, S.J. Hinder, J.F. Watts, C. Lekakou, *J. Power Sources* **561**, 232762 (2023). <https://doi.org/10.1016/j.jpowsour.2023.232762>

Appendix

Here are three manuscript introductions produced by ChatGPT in response to three possible prompts. We tried different possible variants of prompts and those reproduced here gave the best responses. When you ask it to include references to the original work, it appears to do a professional job, only

that the references produced are mostly fake. Only in one instance did it include a genuine reference.

Prompt 1: Write a research manuscript introduction for an article based on the crystalline sponge method. Include references to the original work cited. (For comparison, please check the introduction sections of References 9 and 10.)

ChatGPT: *The development of new materials with improved properties and functionalities has been a major goal in the field of materials science. In particular, the synthesis of new materials with unique structures and properties is of great interest for a wide range of applications, including energy conversion and storage, catalysis, and electronics (Wang et al., 2019).*

One of the most promising approaches to synthesise new materials with unique structures is the crystalline sponge method, which involves the self-assembly of nanocrystals into highly porous 3D frameworks with well-defined structures and morphologies (Sun et al., 2018). The porous nature of the crystalline sponge materials allows for the facile incorporation of different functional groups and the tuning of their properties, making them suitable for various applications, such as catalysts, supercapacitors, and battery materials (Li et al., 2020).

Despite the great potential of crystalline sponge materials, their synthesis and characterizations remain challenging, and the development of new methods to improve their performance and stability is ongoing (Zhang et al., 2021). Moreover, the fundamental understanding of the structure–property relationships of these materials and their potential applications remains limited, and more research is needed in this field.

The objective of this study is to review the recent advances in the field of crystalline sponge materials, including their synthesis, characterization, and potential applications. This review will provide a comprehensive overview of

the current state of the field, highlighting the key advances and challenges in the development of crystalline sponge materials. Additionally, this review will provide valuable insights into the future directions for the field and the potential impact of crystalline sponge materials on various technological areas, based on the original work cited in the literature.

References

1. Li, X., Chen, L., & Xu, J. (2020). Crystalline sponge materials: synthesis, properties, and applications. *Chemical Society Reviews*, 49(2), 526–546.
2. Sun, Y., Liu, J., & Wang, Z. (2018). Synthesis of crystalline sponge materials and their applications in energy storage. *Energy & Environmental Science*, 11(1), 33–44.
3. Wang, J., Li, Y., & Wang, X. (2019). Crystalline sponge materials: Synthesis, characterization, and applications. *Frontiers in Materials*, 6, 104.
4. Zhang, X., Zhang, H., & Zhang, Y. (2021). Crystalline sponge materials: Synthesis, properties, and perspectives. *Frontiers in Materials*, 8, 721.

Prompt 2: Write a research manuscript introduction for an article based on Ruddlesden-Popper phase materials applications in solid oxide cells. Include references to the original work cited. (For comparison, please check the introduction sections of References 11 and 12.)

ChatGPT: *Solid oxide cells (SOCs) have gained significant attention as a promising technology for clean energy generation and storage due to their high efficiency and versatility. The use of suitable electrode materials is crucial for the successful operation of SOCs, and the search for new materials that can improve the performance and stability of these devices is ongoing (Nagarajan et al., 2018).*

Ruddlesden-Popper (RP) phase materials, also known as layered perovskites, have recently emerged as promising electrode materials for SOCs due to their unique electronic and optical properties (Zhou et al., 2020). The layered structure of RP phase materials enables the tuning of their electronic properties by varying the composition and size of the perovskite layers, making them suitable for a wide range of applications,

including photovoltaics, catalysis, and thermoelectrics (Chen et al., 2019).

Despite the promising properties of RP phase materials, the development of these materials for practical applications in SOCs remains challenging due to the difficulty in controlling their synthesis and the stability of the materials over time (Wang et al., 2020). However, recent studies have shown that RP phase materials have the potential to significantly improve the performance and stability of SOCs (Zhang et al., 2021).

The objective of this study is to review the recent developments in the field of RP phase materials as electrode materials for SOCs, including their synthesis, characterization, and potential applications. This review will provide a comprehensive overview of the current state of the field, highlighting the key advances and challenges in the development of RP phase materials for SOCs. Additionally, this review will provide valuable insights into the future directions for the field and the potential impact of RP phase materials on SOC technology, based on the original work cited in the literature.

References

1. Chen, Y., Liu, Y., & Yang, X. (2019). Recent advances in Ruddlesden-Popper phase materials for energy and environmental applications. *Energy & Environmental Science*, 12(9), 2694–2713.
2. Nagarajan, R., Singh, V., & Mukherjee, P. K. (2018). Recent advances in the development of solid oxide fuel cells (SOFCs). *Energy & Environmental Science*, 11(4), 883–910.
3. Wang, L., Gao, Y., & Qi, Y. (2020). Synthesis and characterization of Ruddlesden-Popper perovskite-based materials for energy applications. *Frontiers in Energy Research*, 8, 565,924.
4. Zhang, J., Zhang, Q., & Zhang, Y. (2021). Ruddlesden-Popper phase materials for energy and environmental applications: Synthesis, properties, and perspectives. *Frontiers in Energy Research*, 9, 641,348.
5. Zhou, Z., Cai, Y., & Wang, X. (2020). Ruddlesden-Popper perovskites as electrode materials for solid oxide cells: A review. *Journal of Materials Chemistry A*, 8(32), 16,254–16,269.

Prompt 3: Write a research manuscript introduction for an article on lithium-ion batteries with a focus on their safety and power density considerations. Include references to the

original work cited. (For comparison, please check the introduction sections of References 13 and 14.)

ChatGPT: *Lithium-ion batteries (LIBs) are widely used in various applications due to their high energy density and long cycle life. However, safety concerns and the demand for higher power density have become significant challenges in the development of LIBs.*

The safety issues of LIBs arise from the flammability of the organic electrolyte, which can cause thermal runaway and lead to catastrophic failure. The power density of LIBs is limited by the slow diffusion of lithium ions in the solid electrolyte and the low electronic conductivity of the active materials.

In recent years, numerous efforts have been made to improve the safety and power density of LIBs. One approach is to replace the organic electrolyte with a solid-state electrolyte, which can eliminate the risk of thermal runaway and improve the power density by increasing the ionic conductivity. Another approach is to develop new active materials with

high electronic conductivity and high lithium-ion diffusivity, such as silicon-based anodes and nickel-rich cathodes (Wang et al., 2015; Manthiram et al., 2016).

This research aims to investigate the safety and power density of LIBs by developing new solid-state electrolytes and active materials with improved properties. Our work will build upon previous studies on LIBs (Wang et al., 2015; Manthiram et al., 2016) and will contribute to the development of a materials design strategy that takes into account both safety and power density considerations.

To achieve our objective, we will use a combination of advanced materials synthesis techniques, such as sol-gel and high-temperature solid-state reactions, and characterization techniques, such as impedance spectroscopy and scanning electron microscopy. Our findings will provide new insights into the development of safe and high-power-density LIBs, which will be valuable for the advancement of energy storage technologies.

In conclusion, this research aims to address the safety and power density considerations of LIBs by developing new solid-state electrolytes and active materials. Our findings will contribute to the advancement of energy storage technologies and have the potential to impact various applications, such as electric vehicles and grid storage.

References

1. Wang, X. et al. (2015). Energy & Environmental Science.
2. Manthiram, A. et al. (2016). Nature Reviews Materials.

Only Reference 1 produced in response to prompt 3 regarding Li-ion batteries is genuine. All other references are made up and a significant cause for worry. Nevertheless, we are optimistic about ChatGPT and other related technologies and believe that they would be helpful for scientists, but the user needs to observe extreme care and weed out false information and fake references. ChatGPT ultimately would be a tool and surely would not replace scientists.

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