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The Carbon and Carbon Trends Journals in the era of Artificial Intelligence (AI) and assisted technologies

The use of artificial intelligence (AI) tools is increasing in prominence in many professions, sectors, and spheres of life from [diagnosis in the medical field](#) to [automated computer code generation](#). Recently, the use of AI tools has generated a wide debate within the academic world with regard to teaching and research, especially regarding where the boundary lies with respect to originality, ownership and ethics.

As a response to an increasing number of activities around artificial intelligence software development and its impact on authoring and publishing practice, a group of Carbon and Carbon Trends editors and publishers have discussed the beneficial and adverse effects of these technologies. The discussion demonstrated the need to share some thoughts, set out the publisher's and journals' position, and help widen the discussion to the research community via this editorial.

We focus first on the recently launched ChatGPT3, a "large language model" AI chatbot built by [OpenAI](#), a company originally funded by Elon Musk and others, and now heavily invested in by Microsoft (chat.openai.com). The software allows free question-and-answer discussion, with conversation history allowing refinement of previous question-responses. It is 'trained' to give realistic responses, although these can sometimes be factually incorrect. It represents a step change from earlier clumsy AI-language models, and five minutes spent playing with ChatGPT3 can quickly convince you of its potential for disruptive impact across many walks of life. The challenges for science and scientific publication will only become more pronounced as it moves incrementally up the S-curve in product development. Microsoft has already announced that it will shortly be implementing a variant into their search engine "Bing", into Microsoft Teams where it will be able to write meeting summaries from video conference calls. Microsoft is also suggesting that it will soon be a feature in their Office suite.

The impact on science and science publishing of "large language models" such as this, and AI in a broader sense, will be significant. In this context, Elsevier has released a general policy concerning the use of such models in the preparation of documents. We summarize here the key points relevant for "Carbon" and its companion journal "Carbon Trends":

Where authors use AI and AI-assisted technologies in the writing process, these technologies should only be used to improve readability and language of the work and not to replace key researcher tasks such as producing scientific insights, analyzing and interpreting data or drawing scientific conclusions. Applying the technology should be done with human oversight and control and authors should carefully review and edit the result, because AI can generate authoritative-sounding output that can be incorrect, incomplete or biased. The authors are ultimately responsible and accountable for the contents of the work.

Authors should disclose in their manuscript the use of AI and AI-assisted technologies and a statement will appear in the published work. Declaring the use of these technologies supports transparency and trust between authors, readers, reviewers, editors and contributors and facilitates compliance with the terms of use of the relevant tool or technology.

Authors should not list AI and AI-assisted technologies as an author or co-author, nor cite AI as an author. Authorship implies responsibilities and tasks that can only be attributed to and performed by humans. Each (co-) author is accountable for ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved and authorship requires the ability to approve the final version of the work and agree to its

submission. Authors are also responsible for ensuring that the work is original, that the stated authors qualify for authorship, and the work does not infringe third party rights, and should familiarize themselves with our [Ethics in Publishing policy](#) before they submit.

As with any disruptive technology, there is great potential associated with AI models and machine learning in general, both positive and negative. AI language models can certainly help bridge language barriers, making it easier for researchers to share their findings with colleagues across the globe. By automating some aspects of the writing process, researchers can focus more on the scientific content and less on the mechanics of writing. These models can help with filtering and accessing the large quantities of scientific information available in the literature and elsewhere. Machine learning in a wider sense can be an important tool in carbon science, impacting on data analysis, relevant signal extraction, identifying “hidden” correlations, and other areas. Techniques that generate large amounts of data (e.g., electron micrographs, spectroscopy data, scanning probe micrographs, etc.) are particularly amenable to improved analysis using AI models, and atomic-scale carbon modelling is undergoing a revolution with the arrival of machine-learning generated potentials such as GAP [<https://doi.org/10.1063/5.0005084>]. Data-driven Materials Science as an emerging discipline can be described as the fourth scientific paradigm (Figure 1). The use of machine learning in carbon science is discussed further in the 2022 Carbon Science perspectives editorial [<https://doi.org/10.1016/j.carbon.2022.04.015>].

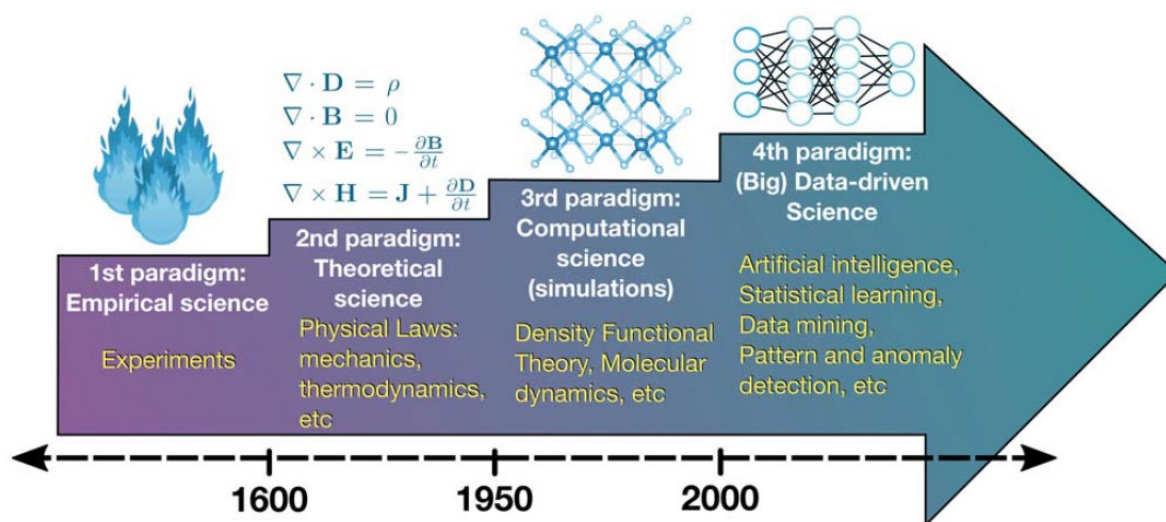


Figure 1: The four science paradigms : empirical, theoretical, computational, and data-driven. Each paradigm both benefits from and contributes to the others. Reproduced from G. R. Schleder et al, *J. Phys. Mater.* 2 032001 (2019).

At the same time, uncontrolled massive use of AI tools in publishing can, perhaps unwittingly, enable growth in scientific fraud. While ChatGPT3 and similar tools can certainly aid in speeding the generation of articles and results more efficiently, they are not a viable replacement for careful scientific communication, argument, analysis and peer review. In general, one should not view AI tools as a threat to the scientific endeavour but rather as a positive tool, which if used responsibly, can greatly advance our scientific understanding and exchange. We need to redouble individual and collective efforts to ensure that reproducibility and solid scientific discovery continue to pave the way to progress. This calls for the renewed importance of properly citing state-of-the-art research, with a greater emphasis on result reproduction and verification.

More generally we need to continue encouraging the widespread use of data sharing and develop open data standards, sharing raw source data where possible (using open source repositories such as

data.mendeley.com, zenodo.org and services such as openaire.eu). It is important to support forums discussing this and other related issues in data reproducibility, access and standards and ultimately converge to a common view. Furthermore, with the advent of AI tools, it is more important than ever to stress the importance of reporting negative results: just like us humans, AI tools can learn as much from negative results as they do from positive ones.

It is almost impossible to predict how much impact AI- and AI-tools will have in even 12 months' time, and thus it is premature for us to develop a general editorial stance on AI and AI-tools. The Carbon and Carbon Trends editorial team is continuously monitoring the field and our journals' policy will evolve as appropriate in a timely manner. We encourage our authors to focus their efforts on improving the scientific method emphasizing novelty, reproducibility, and data sharing. If AI is used as part of the methodology, then it is right to acknowledge its role, but it should never be used to undermine the authenticity or originality of science and its communication... ultimately the responsibility will continue to rest with the authors.

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