

Generative artificial intelligence and scientific integrity

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Abstract

Generative artificial intelligence has undeniable benefits, but it raises important ethical questions, such as its impact on individual autonomy and responsibility, social inclusion, cultural identity, security, fair distribution of benefits, accountability, and even the environment. This article aims to bridge the gap between the numerous benefits of generative artificial intelligence for medicine and society and, at the same time, to reflect on and make recommendations for ethical, responsible, and trustworthy generative artificial intelligence, especially regarding how science is conducted and its use in teaching and research with complete scientific and academic integrity, in a clear exercise of anticipatory technological ethics. Creating clear rules for the responsible use of generative artificial intelligence is an existential ethical challenge.

Keywords: Artificial intelligence. Bioethics. Science. Medicine. Social responsibility. Trust.

Resumo

Inteligência artificial generativa e integridade científica

A inteligência artificial generativa tem inegáveis benefícios, mas coloca importantes questões de natureza ética, tais como seu impacto na autonomia e responsabilidade individuais, na inclusão social, na identidade cultural, na segurança, na justa distribuição dos benefícios, na prestação de contas ou mesmo no ambiente. Neste artigo, pretende-se efetuar a ponte entre os inúmeros benefícios da inteligência artificial generativa para a medicina e para sociedade e, simultaneamente, efetuar uma reflexão, com consequentes recomendações, sobre uma inteligência artificial generativa ética, responsável e de confiança, sobretudo no que diz respeito ao modo como se faz ciência e a sua utilização no ensino e na pesquisa com total integridade científica e acadêmica, em um exercício claro de ética tecnológica antecipatória. Trata-se de desafio ético existencial criar regras claras para a utilização responsável da inteligência artificial generativa.

Palavras-chave: Inteligência artificial. Bioética. Ciência. Medicina. Responsabilidade social. Confiança.

Resumen

Inteligencia artificial generativa y integridad científica

La inteligencia artificial generativa tiene beneficios innegables, pero plantea importantes cuestiones de naturaleza ética, como su impacto en la autonomía y la responsabilidad individuales, la inclusión social, la identidad cultural, la seguridad, la distribución justa de los beneficios, la rendición de cuentas o incluso el medio ambiente. En este artículo se pretende tender un puente entre los innumerables beneficios de la inteligencia artificial generativa para la medicina y la sociedad y, al mismo tiempo, reflexionar, con las consiguientes recomendaciones, sobre una inteligencia artificial generativa ética, responsable y fiable, sobre todo en lo que respecta a la forma de hacer ciencia y su uso en la enseñanza y la investigación con total integridad científica y académica, en un claro ejercicio de ética tecnológica anticipatoria. Se trata de un desafío ético existencial crear reglas claras para el uso responsable de la inteligencia artificial generativa.

Palabras clave: Inteligencia artificial. Bioética. Ciencia. Medicina. Responsabilidad social. Confianza.

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While it is true that artificial intelligence (AI) is decisively changing our collective lives, generative artificial intelligence (GenAI) is the most visible example of this transformation. Different AI systems have been introduced to the global market in recent years—among them ChatGPT and DeepSeek—and have irreversibly altered the way scientific knowledge is conceived, conducted, and applied in medicine and biomedical sciences.

While the benefits of GenAI are undeniable, this technology raises important ethical questions, including its impact on individual autonomy and responsibility, social inclusion, cultural identity, security, accountability, and the environment. This article aims to bridge the gap between the numerous benefits of GenAI for medicine and society and, simultaneously, to reflect on and make recommendations for ethical, responsible, and trustworthy generative artificial intelligence, especially regarding how science is conducted and its use in teaching and research with complete scientific and academic integrity.

Generative artificial intelligence in education and research

Generative artificial intelligence is a type of technology that uses AI to create content, including text, video, and images. GenAI is “trained” by searching for patterns in large amounts of data (training data) to generate new content. It is a technology that mimics human intelligence in its creative process and in its predictions, and tends to evolve as it trains on additional data. In other words, it learns to learn autonomously. It relies on AI models and algorithms trained on unlabeled data collections and demands enormous computational power for its application. GenAI, specifically ChatGPT, has democratized access to AI by making it easy to use across the most diverse domains of activity¹.

As mentioned, some generalized examples of GenAI are ChatGPT, DeepSeek, Claude, Gemini, and DALL-E. Given that these are deep learning models that rely on provided training data,

important ethical questions arise². GenAI often takes the form of “conversational intelligence,” i.e., a tool that helps to communicate with human beings more efficiently, spontaneously, and naturally. It is a dialogue with reciprocal conversation—questions and answers—which, associated with generative technology, can significantly increase the efficiency and dissemination of research and knowledge. It should be clear that the responsibility for the research results and their application lies with the researchers, and it is not legitimate, at least for now, to hold GenAI responsible for these consequences³.

Due to its ethical impact, GenAI is increasingly resorting to synthetic data—data generated by AI—which may be a solution to overcome the impossibility of anonymizing or pseudonymizing personal data. Thus, AI can become more robust and reliable, allowing for full protection of sensitive personal data⁴.

While the applications of GenAI in medicine are limitless, for example, in clinical practice⁵, the focus of this article is on how science is done and how scientific knowledge is taught and transmitted. In fact, GenAI is suddenly transforming the way we teach, learn, and investigate in medicine and science⁶. Beyond its already visible impact on how any profession develops, this technology should be appreciated with the necessary critical spirit so that it can be used to optimize research, student education, and professional skill acquisition.

However, a chatbot—i.e., specific software that can hold a conversation in any language—should be noted as being activated by a user-created prompt, i.e., a statement or question in everyday language, which generates a response. This response, in the interlocutor’s language, is obtained through sophisticated statistical methods, but presents different problems, even though the newer versions of the tools are much more sophisticated.

In colloquial terms, GenAI is a “conversational” artificial intelligence, given its mastery of language in any language and its ability to proactively respond to questions posed in prompts, which makes it both very attractive and problematic³. In addition to phenomena of dependence

between GenAI and humans already under evaluation (the development of user affectivity towards AI systems has been proven, with an undeniable impact on mental health), GenAI is an excellent tool, since it creates opportunities that should be leveraged.

Opportunities exist not only in the strict sense of advancing scientific knowledge, but in a broader sense, for example, by contributing to greater inclusion of men and women in accessing and using modern information and communication technologies; however, this seems far from being fully realized. In fact, there seems to be a double narrative: on the one hand, the promise that AI will contribute to greater leadership by women across all activities leveraged by technology; and, on the other hand, real gender disparities in leadership positions and responsibilities in AI research⁷.

Furthermore, GenAI, by generally resorting to bias patterns due to already biased training data collection, may create new forms of “digital divide” based on gender or socioeconomic stratum⁸. Moreover, this digital divide may have important generational contours, as new generations (alpha and beta) will have total immersion in and dependence on new technologies, whereas previous generations exhibit significant digital exclusion.

The “personalization” of contact, particularly in medical education, should be enhanced, especially in a medical environment where professionals have little time to research and teach younger people and therefore frequently resort to telematic communication methods⁹. On the other hand, critical reflection can be stimulated by raising previously unconsidered scientific questions and by combining information available on the internet with information and data specifically provided by researchers. This is, as we shall see, a double-edged sword, since this streamlining can considerably diminish scientific creativity or, at least, the perception of its necessity.

In science and education, GenAI is excellent for translating text and writing papers. However, it has two consequences: the total erosion of data confidentiality, now shared in real time with the

entire scientific and academic community, and a near-total decrease in handwriting. Handwriting should be noted as directly stimulating specific brain regions associated with creativity, coordination, and logical thinking. Therefore, as a suggestion, handwriting should be resumed, at least in part, in basic and higher education, for the harmonious development of the human mind, and even for the preservation of the essentials of human culture and civilization.

With these conditions, there is no doubt that GenAI can contribute to information research and its structured summarization, or to the development of pedagogical content useful to teachers (preparation of materials for use in problems, lesson plans, reports, slides, discussion questions or exam questions, among others), and also to support students (flashcards, summaries, proposed questions on content, among others).

In short, some of the positive and acceptable ways to use GenAI are:

- a. brainstorming ideas through prompts;
- b. assistance in logical reasoning and obtaining explanations about difficult questions and concepts, including in the prompts, the main references of the subject matter in question, to obtain more reliable answers;
- c. assistance in overcoming creative block through interactive dialogue with GenAI;
- d. self-tutoring through conversation with GenAI;
- e. collaborative classes between teachers and students, favoring active learning with the sharing of prompts;
- f. creation of practice questions and self-tests;
- g. organization and summarization of personal notes;
- h. planning and assistance in structuring a work;
- i. help with grammar, spelling, writing, and translation of texts;
- j. summarizing texts, articles, or books (taking into account copyright).

However, with a view to the widespread implementation of an ethical, responsible, and trustworthy GenAI, some potentially disruptive risks must be considered:

- a. The response to the prompt may include biases, distortions/“hallucinations”,

misrepresentations, and plagiarism, depending not only on the type of algorithm (which tends to be improved with new versions), but above all on the training data.

- b.** Academic and scientific fraud, particularly plagiarism, is potentiated by the reproduction of material created by other authors, and the retention of information by the chatbot (prompts and content), which can be reused in response to other authors. Authors, editors, and reviewers should be aware of the possibility of increased plagiarism risk with its use¹⁰. Copyright and plagiarism prevention are some of the main ethical dilemmas of GenAI.
- c.** The generation of knowledge by GenAI can disseminate false information and contribute to the misinformation of society regarding scientific knowledge and research results—e.g., in the case of vaccines or dietary habits. Ensuring the verifiability, reliability, and truthfulness of information is fundamental.
- d.** The possibility of the tool being trained with data adapted to a specific culture and population group generates potentially perverse effects for other cultures. Even within a specific society, such as Brazil or the European Union, GenAI can exacerbate inequalities if not used properly. For example, personalized medicine tends to be developed with specific population groups in mind—primarily Caucasian populations. Hence, the importance of controlling and supervising the flow of information.
- e.** The breach of confidentiality and the lack of privacy protection of unpublished original work, as well as the sharing of researchers' personal data by GenAI companies with third parties, even for commercial purposes¹¹, raise important ethical questions related to data security and protection and the inevitable recourse of citizens to their legitimate "right to be forgotten", i.e., the right to request the deletion of their personal data from digital systems¹².
- f.** The rapid evolution toward fully autonomous systems, coupled with a lack of understanding of their method of operation (black box) due to the lack of explainability of AI, may lead to a lack of effective human supervision of their operation and the necessary replicability and reproducibility of scientific research and, thus, the confirmation of its validity. The rapid evolution of fully autonomous humanoid robots will be one of humanity's greatest challenges, due to their enormous intellectual capacity and the potential for agency and intentionality¹³.
- g.** The encouragement of social isolation among users, with the development of empathy and affection for AI systems, may have serious repercussions on social interaction and solidarity between generations. Above all, the "generation beta" (2025-2039), with high levels of immersion and high dependence on new digital technologies, will be affected by GenAI, with a predictable and strong impact on the evolution of human civilization.
- h.** The possibility of attributing legal personality to AI, and even moral personality¹⁴, leads to a dilution of responsibility for the use of modern digital technologies. It is essential to begin designing a new legal framework to assign responsibility for the consequences of GenAI use, proportional to its level of autonomy.
- i.** International legal regulation is necessary, for example, by generalizing the AI Act, the European Union regulation on artificial intelligence¹⁵, which includes the impact of GenAI on environmental sustainability and One Health.
- j.** The possibility of exacerbating social inequalities at the community level or even globally¹⁶ contributes to social exclusion, and a new form of intergenerational inequality is foreseeable, given that older generations do not have the same digital literacy in AI.

What to do, then? On the one hand, promote literacy throughout the academic and scientific community and the necessary updating of digital skills. This strategy contributes to the digitization of education and the promotion of immersive learning environments. In other words, the aim is for researchers, teachers, and students to learn to learn, learn to ask questions, and learn to criticize, i.e., to develop a critical spirit, both individually and collectively. Some issues require a new ethical

framework in light of the traditional principles of scientific and academic integrity.

First of all, it is important to clarify a central issue at the interface between GenAI, research, and scientific publication: the concept of the author of a work or the publication of research results. According to the International Committee of Medical Journal Editors¹⁷, the following criteria must be cumulatively applied for a researcher to be considered an author: a) substantial contributions to the conception or design of the work, or the acquisition, analysis, or interpretation of data for the work; b) drafting the work or critically reviewing it for important intellectual content; c) final approval of the version to be published; and d) agreement to be responsible for all aspects of the work, ensuring that issues related to the accuracy or integrity of any part of the work are adequately investigated.

Next, the international context of good ethical and integrity practices in scientific research and medical education will be presented, and a link will be made between these principles and the widespread use of generative artificial intelligence.

Ethics, research, and digital technology

Science, particularly in medical and biomedical research, has reached all technological frontiers, raising the question of what its ethical and social limits should be¹⁸. Indeed, the spirit of science is to contribute to humanity's situation and to enable people around the world to access the benefits of scientific progress. Still, there is no doubt that, in many contexts and at the global level, scientists have systematically disregarded ethical principles inherent to the human condition.

Therefore, unsurprisingly, in recent decades, especially after the Nuremberg trials, relevant conventions have been proclaimed internationally by different political institutions¹⁹ but sharing the same ideals: to preserve the fundamental values of humanity, to promote human rights and human dignity, to protect the environment and, obviously, to promote the ideal that the interests of the

person should always prevail over the interests of science. The Declaration of Helsinki of the World Medical Association²⁰, the Convention on Human Rights and Biomedicine of the Council of Europe²¹, or the Universal Declaration on Bioethics and Human Rights of the United Nations Educational, Scientific and Cultural Organization (UNESCO)²² are some examples of the need for international regulation of science and medical research.

All these instruments, without exception, suggest ethical principles that must be universally respected, which can be summarized as follows: respect for persons and the need for free and informed consent; protection of incompetent persons, namely children (in obtaining the consent of a minor, their opinion must be taken into account according to their age and degree of maturity)²³ and psychiatric patients (consent by the legitimate representative, living will, among others); the ethical imperative to maximize benefits and minimize harm (beneficence and non-maleficence); the right to privacy and confidentiality; justice and equity in access to health care and the benefits of clinical trials; accountability of researchers and institutions that provide health care; and the responsibility of ethics committees.

Evidently, many ethical dilemmas are related to cutting-edge technologies, such as human genome editing and genetic enhancement, precision medicine, synthetic biology, and many other scientific programs that may confront human nature itself, in areas that are today developing in total interdependence with AI. In fact, there is a tendency to compartmentalize science into specific areas, but they all have profound interconnections. Neural networks are a paradigmatic example: as a concept originating in neuroscience, they are now crucial in artificial intelligence. On the other hand, ethical dilemmas may arise in clinical trials, particularly in multicenter research projects conducted by transnational pharmaceutical companies aimed at developing innovative, revolutionary drugs.

Furthermore, how should humanity deal with these ethical challenges? What would be the ethical response of medicine to such dilemmas, particularly in a secular and pluralistic

society? In fact, different conceptions of good are acceptable, as long as scientists' potential conflicts of interest are clearly declared and they act in accordance with ethical and legal principles, especially those agreed upon by the international community.

While the ethical regulation of science takes different forms, there is no doubt that self-regulation is fundamental, especially for personal and professional integrity. There is a growing need to promote integrity as a fundamental ethical value, both in medical training and throughout professional life. Integrity must be valued, pursued, and promoted as an ethical and social value. Ethics committees and professional organizations that regulate professional practice must be particularly aware of the importance of integrity in science, and there must be zero tolerance for deviant behavior.

The global sharing of the benefits of science (open science) and the promotion of the integrity of scientists and institutions may imply a global strategy, because science is driven by multinational organizations, particularly pharmaceutical companies, and especially when it is known that there are global problems that require global responses (as in the case of pandemics). GenAI can be an excellent tool to achieve this goal²⁴. Thus, only truly independent regulatory bodies can defend the public interest and individual rights, especially the rights of the most vulnerable.

Violations of integrity can take many forms: fabrication of data or communication of false results; falsification of research materials; alteration or omission of data; and even plagiarism, driven by financial gain, career advancement, or institutional pressure. Scientific journals should therefore promote more rigorous guidelines for the evaluation, publication, and monitoring of research, especially as GenAI is increasingly implemented.

Since the central goal of science is the pursuit of the common good, selecting reviewers for scientific articles is also a major challenge for scientific journals, because any research proposal must be evaluated in its ethical dimensions, and editors must value true

authorship. Once again, zero tolerance should be the rule, particularly for plagiarism and data or result manipulation.

GenAI exacerbates all these ethical and legal issues, so it is necessary to reinvent the supervision and monitoring processes so that the required replicability of studies (the ability of an independent investigation to reach similar, albeit not identical, conclusions when there are differences in the sample, research procedures and data analysis methods) is a reality that cannot be questioned in its conclusions²⁵.

Replicability²⁶, reproducibility²⁷, and interpretability must be reassessed so that the fiduciary nature between science and society is not questioned. In addition, the dangerous decrease in the levels of freedom in the planning, execution, and analysis of scientific studies²⁸, the progressive commodification of science, and the requirement of peer-reviewed criteria that objectively limit intellectual creativity may be exacerbated in the future by GenAI.

Rigorous mechanisms for holding the scientific community accountable for these practices are necessary, namely, the public disclosure of the scientists and research centers involved. However, the ethical regulation of science should go even further. For example, the peer review process must not only be fair and transparent but also ensure the absolute confidentiality of the research submitted for review. Therefore, any conflicts of interest on the part of both researchers and reviewers are of utmost importance—in particular, the undue influence of pharmaceutical companies seeking to obtain (legitimate) profits after enormous investments in research.

In fact, the total cost of developing a new drug in 2024, from conception to commercialization, including biological drugs, averaged \$2.23 billion for Big Pharma²⁹ in the United States of America. While the corporate social responsibility of pharmaceutical companies should not be questioned, because they fill an important global gap in pharmaceutical research, it is to be expected (though not desirable) that, at times, profit maximization will lead some scientists to overstep their ethical duties.

Ethics in science is always an unfinished task. Only a joint effort by medical schools, professional associations, international regulatory bodies, and especially the personal integrity of researchers can reassure society that the ethos of science will always be respect for the human person and the community of life.

However, the advent of GenAI has the potential to undermine the reliability of science and research, as well as the academic integrity of scientists and institutions. As in medicine, the ultimate goal of its implementation is to help scientists become even better³⁰. The fact that GenAI was initially trained only on information freely available on the internet meant its responses to prompts could be biased by the quality (and eventual lack of veracity) of that information. However, more recent AI systems offer greater reliability and can even select the desired information with some autonomy, making it difficult to verify the validity of the data obtained. Even in the face of evident phenomena of “hallucination” by GenAI, in which the answers are manifestly wrong, there is only a limited capacity for AI to correct this answer³¹.

Thus, implementing intensive digital literacy campaigns from a young age is required, i.e., the ability to identify, understand, interpret, create, and communicate using digital technologies, including digital communication platforms such as social networks, mobile phones, and smart home systems.³²

This refers to the intersection of technological and cognitive skills for processing and sharing information. Critical thinking and creativity are essential for advanced digital literacy. This is an expansive term, but it necessarily includes the effective use of digital technology (including GenAI) and the development of knowledge and skills for its responsible and safe use³³.

In health and research, digital literacy is increasingly important, including the use of electronic health records, telemedicine, digital prescribing, health-related apps, physical exercise, and nutrition. Given its importance in people's daily lives, it is recommended that digital literacy be considered a fundamental competence in the education of children and young people, not only

for its technological component but also for its ethical and social impact.

In fact, and following Lawrence Kohlberg's view³⁴ on the stages of moral development, it is fundamental that the acquisition of digital skills and knowledge of their impact on the community begin as early as possible in childhood and adolescence, so that the human mind, from the earliest stages of personality formation, integrates the handling of digital technology in a way that is both natural and responsible.

The use of GenAI in the production of knowledge and the publication of results is certainly one of the areas that most need in-depth literacy, also to guarantee high levels of integrity and academic commitment in scientific research. Strict rules must be in place to ensure that students, researchers, and scientists know how to use GenAI ethically and comprehensively. To this end, the World Association of Medical Editors presents the following guidelines³⁵:

- a. Chatbots cannot be authors.
- b. Authors should be transparent when using chatbots and should provide information on how they were used:
 - Authors submitting an article in which a chatbot/AI was used to draft new text should note this use in the acknowledgments; all prompts used to generate new text or to convert text or text prompts into tables or illustrations should be specified.
 - When an AI tool, such as a chatbot, is used to perform or generate analytical work, help report results (e.g., by generating tables or figures), or write computer code, this should be stated in the body of the article, both in the abstract and in the methods section. To allow for scientific scrutiny, including replication and the identification of forgeries, full details should be provided on the prompts used to generate the research results, the time and date of consultation, and the AI tool used and its version.
- c. Authors are responsible for the material provided by a chatbot for their article (including the accuracy of what is presented and the absence of plagiarism) and for the proper acknowledgment of all sources (including

the sources of the material generated by the chatbot).

- d. Editors and reviewers must disclose to authors and to each other any use of chatbots in evaluating the manuscript and generating reviews and correspondence. If they use chatbots in their communications with authors and with each other, they must explain how they were used.
- e. Editors must have appropriate tools to help them detect content generated or altered by AI, which should be made available to editors, regardless of their ability to pay for them, for the benefit of science and the general public, and to help ensure the integrity of health care information and reduce the risk of negative health outcomes.

there must be the ability to envision different scenarios for the future of humanity in a clear exercise of anticipatory technological ethics. This is not about restricting the advancement of science or limiting the use of these digital tools, but rather about understanding their evolution, predicting their impact, and anticipating fair and equitable solutions.

The dissemination of harmful content to individuals and organizations is one example that needs to be prevented, as is the intentional or negligent violation of data privacy, which can disclose sensitive and confidential information. On a strictly scientific level, the amplification of existing biases can condition the methods and results of a given study and perpetuate errors that multiply exponentially.

It is therefore an existential ethical challenge to create clear rules for the responsible use of AI, applicable to students, researchers, physicians, and other professionals, so that artificial intelligence is always considered not only trustworthy, but above all, a tool that helps people in their daily lives, in their jobs, and in collective development.

Final considerations

Despite the numerous benefits for medicine and science, generative artificial intelligence raises ethical and social questions of paramount importance that must be considered. Above all,

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Contribution of the authors

Both authors contributed equally to the study (conceptualization, method, writing and review), maintaining equivalent participation.

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