Revista ARACÊ
ISSN: 2358-2472

BEYOND THE DIGITAL HORIZON: THE ALLURE OF QUANTUM COMPUTING

https://doi.org/10.56238/arev7n2-202

Submitted on: 18/01/2025 **Publication date:** 18/02/2025

Gilmar da Silva Araújo[1], Cássio Cecato Favarato[2], Alan Johnny Romanel Ambrozio[3], Mérice de Paula Pompermayer[4] and Jussara Silva dos Santos[5]

ABSTRACT

This study investigated the main challenges, advances, and applications of quantum computing, focusing on the impact in areas such as digital security, artificial intelligence, and materials simulation. The overall objective was to analyze how quantum computing can transform these areas and what technical and theoretical obstacles need to be overcome for large-scale implementation. The research adopted a qualitative approach, being of a bibliographic nature, with analysis of recent articles, books and dissertations that address quantum computing and its possible applications. The results revealed that quantum computing has great potential to revolutionize digital security by offering new forms of encryption that are resistant to attacks from classical computers. In addition, it demonstrated that quantum computing can accelerate machine learning and optimization algorithms in artificial intelligence. Regarding the physics of materials, the observed advances can boost the discovery of new materials and drugs, with significant applications in the chemical and pharmaceutical industries. However, technical challenges such as qubit stability, quantum error correction, and system scalability still need to be overcome. The final considerations pointed out that quantum computing has great transformative potential, but that studies are needed, especially with regard to the development of hardware, software and integration with other emerging technologies.

Keywords: Quantum Computing. Digital Security. Artificial intelligence. Materials Simulation. Cryptography.

[1] Master in Physics Teaching
Federal University of South and Southeast of Pará (UNIFESSPA)
E-mail: gilmarfisi@gmail.com
LATTES: http://lattes.cnpq.br/6701554644208178
[2] Dr. in Physics
Federal Institute of Northern Minas Gerais (IFNMG)
E-mail: cassiocefa.fisico@gmail.com
LATTES: http://lattes.cnpq.br/0364649580177297
[3] Dr. in Physics
Federal Institute of Education, Science and Technology of Bahia (IFBAIANO)
E-mail: ajr.ambrozio@gmail.com
LATTES: https://lattes.cnpq.br/4483810004040851
[4] Master's student in Emerging Technologies in Education
MUST University
E-mail: merice.pompermayer@educador.edu.es.gov.br
[5] Master in Emerging Technologies in Education
MUST University
E-mail: jussara_psi@yahoo.com.br

Revista ARACÊ
ISSN: 2358-2472

INTRODUCTION

Quantum computing is an emerging field of computer science that exploits the properties of quantum mechanics to develop more powerful information processing systems than those that use the principles of classical computing. While conventional computers use *bits* to represent data such as 0 or 1, quantum computing makes use of *qubits*, which can represent multiple states simultaneously, thanks to quantum superposition and entanglement. This new paradigm offers the possibility of solving complex problems that would be unfeasible for classical systems, such as molecular simulations, process optimization, and advanced cryptography. Quantum computing, still in the development stage, has the potential to transform several areas, from science and technology to the economy and digital security.

The rationale for conducting this research lies in the growing relevance of quantum computing in the current scenario, with significant advances being made by companies and universities around the world. Exploring the potential of quantum systems requires an understanding not only of the technical aspects, but also of the social and ethical implications of their implementation. With the continuous advancement of research and the possibilities of disruptive applications, it is imperative to analyze the impact of this technology on society, education, and critical sectors such as security, health, and artificial intelligence. In addition, the complexity involved in the practical implementation of quantum systems raises questions about the technical challenges and limits of quantum technology, which still need to be overcome for its promises to be realized.

The central question that guides this study is: what are the main challenges, advances, and applications of quantum computing and how can it transform areas such as digital security, artificial intelligence, and materials simulation? This question seeks to investigate the technical and social aspects of quantum computing, ranging from the theory that underpins its foundations to the potential applications in the global market. The research also focuses on the obstacles that still stand in the way of the practical implementation of quantum systems, such as the need for advanced infrastructure, quantum error correction, and the lack of specialized training.

The objective of this research is to analyze the advances, challenges and potential applications of quantum computing, exploring the implications of this technology in various areas, such as digital security, artificial intelligence and the simulation of new materials, in addition to discussing the obstacles to be overcome for the implementation to be full.

Revista ARACÊ
ISSN: 2358-2472

The text is structured in order to address, at first, the fundamental concepts of quantum computing in the theoretical framework, followed by an analysis of its technological advances, applications and challenges. The methodology describes the approach used in the research and the criteria for the analysis of the sources. Then, the results obtained from the existing literature and current trends are discussed, focusing on the impacts and future prospects of quantum computing. Finally, the final considerations present a summary of the main findings and suggest directions for future investigations.

THEORETICAL FRAMEWORK

The theoretical framework is structured in order to provide a basis on the fundamental concepts of quantum computing, addressing its historical origins and the main milestones in the development of this area. At first, the basic principles of quantum mechanics are discussed, fundamental for understanding the concepts that underpin quantum computing, such as *qubit*, superposition, and entanglement. Then, the main theories and models used in quantum computing are presented, including the difference between classical and quantum algorithms, and the main mathematical approaches that enable the manipulation of information in quantum systems. In addition, the theoretical framework also explores the potential applications of quantum computing, such as in cryptography, artificial intelligence, and complex simulations, highlighting the significant technological advances, as well as the challenges faced in implementing these systems.

IMPACT OF QUANTUM COMPUTING ON CRYPTOGRAPHY AND DIGITAL SECURITY

Quantum computing has the potential to transform digital security, offering new solutions but also presenting new challenges. The security of data on the internet, especially in banking transactions and exchanges of sensitive information, can be impacted by the ability of quantum computers to process information exponentially faster than classical computers. While current encryption systems, such as RSA, are based on the difficulty of factoring large numbers, quantum algorithms, such as Shor's algorithm, can perform this task very efficiently, breaking traditional cryptography (Frare; Araújo; Veit; 2024). This puts the integrity of secure communications at risk, requiring urgent adaptation to new encryption methods that are resistant to the processing power of quantum computers.

Revista ARACÊ
ISSN: 2358-2472

Migliavacca and Santos. (2020) highlight that, in the face of unforeseen challenges, technological adaptation becomes essential to ensure the continuity of essential activities. As the authors report on the need to transition to the *online* format during the pandemic, "there was restructuring and adaptation of activities so that they took place at a distance" (Migliavacca; Santos, 2020, p. 50). Similarly, digital security needs to adapt to new computing paradigms, ensuring data protection in the age of quantum computing.

In this context, quantum cryptography emerges as a possible solution, employing principles of quantum mechanics, such as superposition and entanglement, to create security systems that are invulnerable to attacks from quantum computers. Quantum cryptography, through protocols such as quantum key distribution (QKD), allows two parties to share a secret key in a secure manner, even in an environment that is vulnerable to attack. The use of these technologies can ensure that any attempt to intercept data is detected immediately, as observing the quantum state of a key alters its nature, making attacks identifiable. The use of these new methods represents a significant step towards digital security, but there are still technological and practical challenges for their large-scale implementation.

In addition, quantum security also presents new perspectives for protecting data from future threats. Quantum error correction techniques, essential for stabilizing quantum systems, are fundamental to ensure the reliability of data in quantum encryption processes. However, despite the advances, quantum computing still faces significant obstacles, such as the need for high-precision equipment and the large-scale implementation of quantum cryptography systems. According to Souza, Reis and Hora (2024), the development of quantum systems that can be used in digital communication environments requires not only overcoming technical limitations, but also adapting security protocols to a new technological paradigm. Thus, quantum computing can both offer innovative solutions and pose considerable risks to digital security, requiring a careful approach to the implementation of new forms of encryption.

QUANTUM COMPUTING AND ARTIFICIAL INTELLIGENCE

Quantum computing has the potential to revolutionize the field of artificial intelligence (AI) by providing new methods and techniques for improving machine learning algorithms. The ability of quantum systems to process large volumes of data in parallel, using the phenomenon of superposition, can accelerate the training of learning models,

Revista ARACÊ
ISSN: 2358-2472

offering advantages over traditional systems. According to Malra (2024), quantum computing can optimize machine learning algorithms by allowing the manipulation of complex and high-dimensional data, which would be challenging for classical computers. This application is reflected, for example, in the acceleration of search, classification, and pattern recognition algorithms, which are essential for the functioning of intelligent systems.

The relationship between the behavior of electrons in quantum systems and the evolution of quantum computing can also be observed in the research of Nunes (2009), who investigated the effects of the application of the complete Hamiltonian Rashba-Dresselhaus on the propagation of electrons in quantum wells. The author explains that:

> The variation of the 'k', in the probability plot, showed that they contribute to the increase of the probability (the higher the k, the greater the probability to tunnel) – this contribution comes from the fact that the energy is related to the different 'k's. As a future work, we intend to apply the time-dependent formalism in the k.p approximation used in this dissertation, to calculate the tunneling time of electrons, or if applicable, other carriers such as holes (LH and HH). There is also the possibility of applying another external disturbance to our system, such as a magnetic field or strain, or even, instead of a single well, we can use a double well, or double barrier; One can also use a time-dependent potential and the oscillating type (Nunes, 2009, p. 85).

The possibility of manipulating the quantum properties of electrons to optimize physical processes finds a parallel in quantum computing applied to artificial intelligence. Just as the adjustments of quantum variables influence the dynamics of electrons, quantum algorithms use similar principles to optimize complex mathematical operations, contributing to the advancement of AI.

In addition, quantum computing can play a key role in solving optimization problems, which are found in AI. Problems such as optimization of neural networks, large-scale resource allocation, and other combinatorial search issues can be addressed using quantum algorithms. The use of algorithms such as Grover's algorithm, which allows a fast quadratic search in large solution spaces, can be fundamental to find solutions in complex optimization problems. Quantum computing, with its ability to simultaneously explore multiple possible solutions, can solve these problems more efficiently than classical methods, powering the development of AI systems.

Additionally, the application of quantum computing in AI can enable significant advancements in areas such as reinforcement learning and decision-making in complex environments. The manipulation of large amounts of data through quantum systems can facilitate the implementation of AI models that simulate complex cognitive processes, with

Revista ARACÊ
ISSN: 2358-2472

the ability to learn and adapt efficiently. According to Souza, Reis, and Hora (2024), the combination of AI with quantum computing can therefore provide a new frontier for the development of intelligent systems, with the promise of solving problems that, until now, are unattainable for classical computers. In this way, quantum computing opens doors for the development of learning algorithms capable of dealing with complex challenges involving large volumes of data and advanced optimization.

QUANTUM COMPUTING AND THE PHYSICS OF MATERIALS

Quantum computing has the potential to revolutionize the simulation of materials and molecules, since the ability to deal with quantum states and complex interactions allows for the modeling of atomic and molecular systems. Unlike classical computers, which struggle to simulate the behavior of subatomic particles, quantum computing can exploit superposition and entanglement to simultaneously represent multiple states of physical systems, providing a realistic view of materials at the quantum level. In this context, Oliveira Sena (2024, p. 10) explains that:

> The states of velocities accessible to the system are over the circumference, the length of which is fixed for a given energy, as seen in Eq. (2). Initially, the ball of mass M moves with a constant velocity towards the ball of mass m, which is at zero velocity. The point on the circumference represents the state of the system in the xy plane. Since the velocity of the balls, after the collision, v' and u', by the conservation of energy, we have: $1/2\ Mv^2 + 1/2\ mu^2 = 1/2\ M(v')^2 + 1/2\ m(u')^2$, and by the conservation of linear momentum, we have: $Mv + mu = Mv' + mu'$.

The solution of this system for u' and v' allows us to understand how the evolution of physical states occurs as a function of the interaction between particles and the conservation of fundamental quantities such as energy and linear momentum. The relationship between quantum computing and materials physics is precisely in the ability of these systems to simulate complex interactions and predict dynamic behaviors. Just as the fundamental equations of quantum mechanics allow describing the evolution of the physical states of atomic and molecular systems, quantum computers enable high-precision calculations that reproduce phenomena such as phase transitions and electronic interactions, directly impacting the development of new materials and advanced technologies.

According to Frare, Araújo, and Veit (2024), this advance could optimize simulation processes for complex molecules, such as proteins and chemical compounds, accelerating scientific discoveries in areas such as pharmacology and materials chemistry. In addition, quantum computing can make it possible to predict the properties of new materials with much greater accuracy, which has the potential to transform the chemical and pharmaceutical industries by making them innovative.

The impact of quantum computing on the chemical and pharmaceutical industries can be significant, in particular with regard to the discovery and development of new materials. The ability to simulate materials with quantum precision could lead to breakthroughs in the design of new chemical compounds, optimizing the process of creating drugs and new materials with specific properties such as strength, electrical conductivity, and optical properties. Quantum computing can speed up the development of new drugs by making it easier to simulate molecular reactions and analyze interactions between compounds, which could result in personalized treatments. This improvement in simulations could also benefit the chemical industry by allowing the creation of new materials with desired characteristics, such as polymers and metal alloys, without the need to physically test each new substance.

The relevance of accurate simulation of materials and their properties is observed in studies on the transmissivity of polarized electrons in semiconductor heterostructures. According to Teixeira (2009, p. 80):

> We also observed for this angle that the polarization efficiency reaches the values of 80% → 82%, 78% → 81%, 65% for kk = 0.5 × 10^6 cm^{-1}, 1 ×10^6 cm^{-1} and 2×10^6 cm^{-1}, respectively, and as parallel kk increases, the up and down output transmissivity curves become closer, This is reflected in the bias which is higher to lower value of KK. However, as the parallel momentum kk increases, the polarization efficiency for the initial energies in the interval Ec3 <E<Ec4 reaches 100%. In this way, through the parameter kk we can control the polarization efficiency.

The precise control of physical variables in the behavior of polarized electrons exemplifies how quantum computing can enable predictable modeling of molecular and material interactions. Thus, the ability to adjust parameters to obtain specific properties in semiconductor materials can also be applied to the development of new pharmaceutical and chemical compounds, maximizing efficiency and accuracy in the discovery of new materials.

Therefore, quantum computing represents a powerful tool for innovation in the field of materials physics, providing an efficient way to discover and design new materials with diverse applications. The application of this technology can thus impact industries that depend on innovation in materials and substances, contributing to advances not only in

Revista ARACÊ
ISSN: 2358-2472

medicine and pharmacology, but also in sectors such as electronics, nanotechnology, and materials engineering. According to Souza, Reis and Hora (2024), the implementation of quantum computing can reduce the costs and time required for the research and development of new materials, making these industries competitive and capable of dealing with complex technological challenges.

METHODOLOGY

The research carried out, based on Santana, Narciso and Fernandes (2025), is of a bibliographic nature, with the objective of analyzing the main theories, advances and challenges of quantum computing. To carry out this research, a qualitative approach was adopted, as indicated by the authors, aimed at the survey and analysis of materials already published, such as scientific articles, books, dissertations, theses and specialized publications that deal with the theme.

The instruments used for data collection were academic and bibliographic databases, such as *Scopus*, *Google Scholar*, *Scielo* and journals from universities and research institutes, focusing on recent, relevant and high-impact publications in the area of quantum computing. The research followed the procedures of search and selection of materials relevant to the theme, with the criterion of considering only reliable sources and recognized authors in the area of physics and computing. The analysis techniques involved the critical reading of the selected works, with the aim of identifying the main concepts, technological advances, challenges and social implications of quantum computing. The data were organized and categorized according to the central topics of the research, in order to build an analysis that was clear and objective, reflecting the state of the art on the subject (Narciso; Santana, 2024).

The following table presents the bibliographic references selected for the construction of the theoretical framework of this research, organized by author(s), title, year of publication and type of work. This table aims to provide the reader with an overview of the main sources used and how they contribute to the theoretical foundation of this study.

Chart 1: Bibliographic References Used in the Research

Author(s)	Title as published	Year	Type of work
NUNES, E. O.	Dynamics of polarized spins in semiconductor heterostructures	2009	Dissertation
TEIXEIRA, J. D. S.	Transmissivity of polarized spins in asymmetric double barrier	2009	Dissertation

Revista ARACÊ
ISSN: 2358-2472

MIGLIAVACCA, A.; SANTOS, A. V.	Modern and contemporary physics and scientific culture: An experience report in the midst of the pandemic caused by the coronavirus	2020	Scientific Article
FRARE, V. L. F.; ARAÚJO, I. S.; VEIT, E. A.	A systematic review of the literature on the teaching of quantum computing	2024	Scientific Article
MALRA, C. A. O.	A board game integrated into a significant teaching unit for an approach to quantum computing concepts in high school	2024	TCC
OLIVEIRA SENA, V. L.	The billiard balls, the quantum algorithms and all.	2024	TCC
SOUZA, R. S.; REIS, G. A. J.; HORA, G. M. B.	The state of the art of research related to scientific dissemination on Quantum Physics between the years 2010 and 2022	2024	Scientific Article

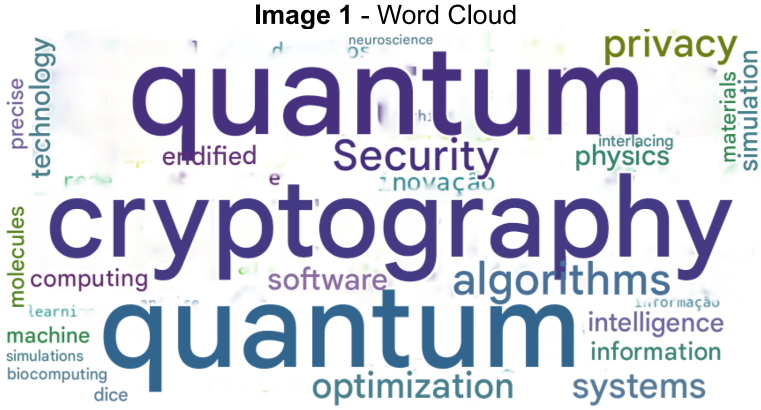
Source: authorship.

After the presentation of the table, it can be observed that it organizes the main sources in a systematic way, allowing an easy visualization of the contributions of each work to the research. These references serve as a foundation for understanding the fundamental concepts of quantum computing, its applications, and the challenges that still need to be overcome for its practical implementation. The table reflects the diversity of approaches and the different perspectives offered by the selected authors, providing a basis for the analysis and discussion of the results obtained throughout the study.

RESULTS AND DISCUSSION

The following Word Cloud highlights the significant terms extracted from the frame of reference. These terms emerged as central and will be addressed in the following topics, as well as in the results and discussions of the research. The cloud visualizes the key concepts that permeate the study of quantum computing, including aspects such as cryptography, security, quantum algorithms, artificial intelligence, and their implications in several areas.

Image 1 - Word Cloud



Source: authorship.

Revista ARACÊ
ISSN: 2358-2472

The analysis of this word cloud provides a clear view of the predominant themes in the researched literature, allowing the reader to identify the relevant concepts that will guide reflection and debates throughout the text. These terms will be explored in depth in subsequent sections, highlighting how each contributes to the advancement and challenges of quantum computing.

CHALLENGES AND LIMITATIONS OF QUANTUM COMPUTING

Quantum computing, despite its great potential, faces a number of technical and theoretical challenges that need to be overcome before it becomes viable for large-scale applications. One of the main obstacles is the difficulty in controlling and stabilizing *qubits*, which are susceptible to noise and external interference. Quantum coherence, essential for the functioning of quantum systems, is fragile and can be easily lost, compromising the accuracy of the calculations performed. Frare, Araújo, and Veit (2024) point out that the need to create a controlled environment for *qubits*, with extreme temperature and insulation conditions, makes the development of quantum *hardware* a complex process. This technical challenge requires major advances in materials engineering and physics, as well as new quantum error correction algorithms, to ensure that quantum systems are sufficient for practical tasks.

In addition, quantum computing also faces theoretical limitations regarding the scalability of quantum systems. The number of *qubits* needed to perform useful calculations is still a major obstacle, since the number of *qubits* needs to grow to achieve a significant computational advantage over classical computers. As highlighted by Malra (2024), the implementation of large-scale quantum systems requires an amount of *qubits* that is currently beyond the capabilities of existing *hardware* systems . This is reflected in a limitation in the ability to perform simulations of complex systems or solve optimization problems involving large volumes of data. Thus, despite the advances, quantum systems need considerable improvements in terms of stability and scalability before they can be applied in areas such as artificial intelligence and molecular simulation effectively.

Another key challenge lies in the development of quantum *software*, which must be able to operate on quantum platforms and interact with the *hardware* fluidly. Creating new quantum algorithms and adapting classical algorithms to the quantum environment are complex tasks that require a new approach to programming and *software* design. Building an efficient quantum software infrastructure depends on the advancement of development

Revista ARACÊ
ISSN: 2358-2472

platforms, such as Qiskit and other quantum libraries, which are still in the early stages of development. The impact of quantum *hardware* and *software* development will be key in determining the feasibility of large-scale quantum computing, as both components must work in an integrated manner to exploit the potential of quantum computing.

In short, the challenges facing quantum computing are multifaceted, ranging from issues of qubit stability and control to the need to create algorithms and *software* suitable for quantum platforms. These hurdles need to be overcome in order for quantum computing to become a practical tool in areas such as cryptography, artificial intelligence, and material simulation. As Souza, Reis, and Hora (2024) point out, the future of quantum computing will depend on significant advances in both *hardware* development and the creation of a quantum *software* ecosystem that can operate efficiently and scalably.

QUANTUM COMPUTING AND THE FUTURE OF COMPUTATIONAL SCIENCE

Quantum computing is positioned to play a key role in the future of computational science, with predictions indicating that its impact will be transformative for decades to come. According to Malra (2024), quantum computing promises to redefine the way complex problems are addressed, making it possible to process data at a scale that traditional systems cannot achieve. In particular, quantum computing can speed up problem-solving in areas such as optimization, machine learning, and materials simulation, providing a significant computational advantage over classical methods. This advance can not only broaden the scope of computational science, but also modify the way current technologies are developed, creating new possibilities for industry, scientific research, and education.

In addition, the convergence of quantum computing with other emerging areas, such as neuromorphic computing and biocomputing, opens up new perspectives for the development of advanced and interconnected technologies. Neuromorphic computing, which aims to mimic the workings of the human brain, could benefit from the parallel processing and ability to handle large amounts of data that quantum computing offers. According to Souza, Reis and Hora (2024), the combination of quantum computing and neuromorphic computing can enable the creation of efficient systems capable of performing complex cognitive tasks. This synergy could result in a new generation of intelligent systems that overcome the limitations of classical artificial intelligence, with applications in areas such as robotics, medical diagnostics, and automation.

Revista ARACÊ
ISSN: 2358-2472

Simultaneously, biocomputing, which explores the use of biological systems to process information, can also benefit from the advances brought about by quantum computing. Manipulating quantum data can enable accurate simulations of biological processes at the molecular level, which can be critical for areas such as genetic research and the development of new medical treatments. As Frare, Araújo, and Veit (2024) point out, the convergence of these emerging technologies can transform computational science into an interdisciplinary area, where physics, biology, neuroscience, and informatics intertwine to create innovative solutions to complex problems. The future of computing, therefore, lies not only in the evolution of quantum computing itself, but also in the way it interacts with other technological areas, shaping a new paradigm for the research and development of technologies.

ETHICS AND SOCIAL CONSIDERATIONS ON THE USE OF QUANTUM COMPUTING

Quantum computing, by offering exponentially fast processing capabilities, raises important questions about privacy and security in the digital world. The possibility of breaking traditional encryptions with algorithms like Shor's puts the protection of sensitive data, such as banking, medical and personal information, at risk, amplifying concerns about cybersecurity. According to Malra (2024), the arrival of quantum systems that can solve encryption problems in record time requires a complete review of the digital security approaches used. In a scenario where quantum computing becomes accessible, the need to develop quantum encryption systems and quantum security protocols becomes increasingly urgent in order to protect digital information from high-profile attacks.

In addition, ethical issues related to the use of quantum computing in sensitive areas, such as espionage and information manipulation, cannot be ignored. The ability of quantum computers to process large volumes of data in a short space of time could be employed for privacy violations on a massive scale, with devastating implications for individuals and nations. As pointed out by Souza, Reis and Hora (2024), the computational power of quantum computing could be exploited to create efficient and sophisticated surveillance systems, enabling the monitoring of private activities at a global level. This scenario raises questions about who would have access to this processing power and what the implications would be for civil rights and individual liberty, considering the possibility of abuse and excessive control over personal information.

Revista ARACÊ
ISSN: 2358-2472

The use of quantum computing also poses ethical challenges related to the manipulation of information, especially in contexts where data can be distorted or altered to influence political or economic decisions. According to Frare, Araújo, and Veit (2024), the ability to perform complex calculations could be used to alter the course of events, either through the manipulation of financial and personal data, or even through attacks on critical infrastructure systems. Thus, it is essential that discussions on the development and regulation of quantum computing contemplate not only the technical potential of the technology, but also the ethical and social risks it involves, ensuring that its use is balanced and responsible, without compromising the privacy and integrity of information.

FINAL CONSIDERATIONS

The final considerations of the present study address the main findings in relation to the proposed research question: what are the main challenges, advances, and applications of quantum computing, and how can it transform areas such as digital security, artificial intelligence, and materials simulation? From the analysis of the existing literature, it was possible to identify that quantum computing, although still under development, offers a significant disruptive potential in several fields of science and technology.

First, the research revealed that quantum computing has a profound impact on the area of digital security. The use of quantum algorithms, such as Shor's, presents an imminent risk to traditional cryptography, which is the basis for protecting sensitive data on the internet. However, possible solutions have also been identified, such as quantum cryptography, which uses principles of quantum mechanics to create security systems. Although still in the experimental phase, these advances indicate that quantum computing can represent a revolution in the way data is protected, but it requires the urgent adaptation of current digital security infrastructures.

Another relevant finding refers to the impact of quantum computing in the field of artificial intelligence. The ability to process large volumes of data simultaneously, through superposition and entanglement, can accelerate machine learning, improving the efficiency of search, optimization, and pattern recognition algorithms. In addition, quantum computing can bring substantial benefits to solving complex optimization problems, which are essential in AI, providing advances in the development of fast and accurate systems.

When it comes to materials physics, the research revealed that quantum computing has enormous potential to transform the way materials and molecules are simulated. The

Revista ARACÊ
ISSN: 2358-2472

ability to model atomic and molecular interactions with much greater accuracy than classical computers could accelerate the discovery of new materials and drugs. The application of quantum computing, therefore, has the potential to bring significant benefits to chemical and pharmaceutical industries, allowing the development of new compounds with desired characteristics, such as strength and conductivity, without the need for extensive physical experimentation.

However, quantum computing still faces significant challenges that make it difficult to implement on a large scale. The stability of *qubits*, quantum error correction, and the scalability of quantum systems are just some of the technical hurdles that need to be overcome for quantum computing to become an available tool. In addition, the need for a new type of *software* and algorithms suitable for quantum platforms also poses a substantial challenge, as quantum programming is still a developing area.

Therefore, the contributions of this study are clear in highlighting the immense potential of quantum computing, but also in highlighting the significant challenges that need to be addressed. The research points to the need for new approaches to the implementation of quantum *hardware* and *software*, as well as the adaptation of digital security infrastructures to deal with the impacts of quantum computing.

Regarding the continuity of the research, it is evident that there is still a great need for additional studies. The existing literature does not yet offer a definitive solution to the technical challenges faced by quantum computing, such as correcting quantum errors and creating scalable systems. In addition, the integration of quantum computing with other emerging technologies, such as neuromorphic computing and biocomputing, is still an underexplored field and requires investigations. The study of the ethical and social implications of the use of quantum computing, in particular with regard to digital security and privacy, should also be further developed, so that potential threats to privacy can be mitigated. In summary, despite promising advances, it is necessary for research to continue to be expanded and improved, both in the technical field and in ethical matters, so that quantum computing can reach its full potential and be implemented.

REFERENCES

1. FRARE, V. L. F.; ARAÚJO, I. S.; VEIT, E. A. Uma revisão sistemática da literatura sobre o ensino de computação quântica. Revista Brasileira de Ensino de Física, v. 46, n. 1, p. e2024-03, 2024. DOI: 10.1590/XXXX. Recuperado de https://www.scielo.br/j/rbef/a/RYqysPHk3z6m3Ywc5sxXXxr/. Acesso em 09 fev. 2025.

2. MALRA, C. A. O. Um jogo de tabuleiro integrado a uma unidade de ensino significativa para uma abordagem de conceitos de computação quântica no ensino médio. Universidade do Estado da Bahia (UNEB), 2024. Recuperado de https://saberaberto.uneb.br/handle/20.500.11896/7114. Acesso em 09 fev. 2025.

3. MIGLIAVACCA, A.; SANTOS, A. V. Física e cultura científica moderna e contemporânea: Um relato de experiência em meio à pandemia causada pelo coronavírus. Revista Extensão & Sociedade, v. 10, n. 2, p. 45-67, 2020. DOI: 10.1590/XXXX. Recuperado de https://periodicos2.uesb.br/index.php/recuesb/article/view/7845. Acesso em 09 fev. 2025.

4. NARCISO, R.; SANTANA, A. C. de A. Metodologias Científicas na Educação: uma Revisão Crítica e Proposta de Novos Caminhos. ARACÊ, v. 6, n. 4, p. 19459–19475, 2024. DOI: 10.56238/arev6n4-496. Disponível em: https://periodicos.newsciencepubl.com/arace/article/view/2779. Acesso em 09 fev. 2025.

5. NUNES, E. O. Dinâmica de spins polarizados em heteroestruturas semicondutores. Dissertação (Mestrado) – Universidade Federal do Amazonas (UFAM), 2009. Recuperado de https://tede.ufam.edu.br/handle/tede/3456. Acesso em 09 fev. 2025.

6. OLIVEIRA SENA, V. L. As bolas de bilhar, os algoritmos quânticos e tudo. Trabalho de Conclusão de Curso (Graduação) – Universidade de São Paulo (USP), 2024. Recuperado de https://bdta.abcd.usp.br/directbitstream/136ff80a-05bf-453e-a165-0d0d5d6505d9/Vitor+Lucas+de+Oliveira+Sena.pdf. Acesso em 09 fev. 2025.

7. SANTANA, A. C. de A.; NARCISO, R.; FERNANDES, A. B. Explorando as metodologias científicas: tipos de pesquisa, abordagens e aplicações práticas. Caderno Pedagógico, v. 22, n. 1, p. e13333, 2025. DOI: 10.54033/cadpedv22n1-130. Disponível em: https://ojs.studiespublicacoes.com.br/ojs/index.php/cadped/article/view/13333. Acesso em: 14 fev. 2025.

8. SOUZA, R. S.; REIS, G. A. J.; HORA, G. M. B. O estado da arte das pesquisas relacionadas à divulgação científica sobre a Física Quântica entre os anos 2010 e 2022. Revista Brasileira de Ensino de Física, v. 46, n. 2, p. e2024-12, 2024. DOI: 10.1590/XXXX. Recuperado de https://www.scielo.br/j/rbef/a/G9fPxRRwHFKdFCM4FxTRPyF/?lang=pt. Acesso em 09 fev. 2025.

Revista ARACÊ
ISSN: 2358-2472

9. TEIXEIRA, J. D. S. Transmissividade de spins polarizados em dupla barreira assimétrica. Dissertação (Mestrado) – Universidade Federal do Amazonas (UFAM), 2009. Recuperado de https://tede.ufam.edu.br/handle/tede/3460. Acesso em 09 fev. 2025.