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Examining the Impact of Quantum Computing on Education: A Systematic Review

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Abstract

This article analyses the implications of quantum computing in education, highlighting its benefits, such as increased processing capacity and efficient resolution of complex problems. In addition, associated challenges, such as teacher training and curricular adaptation, are examined. Despite these barriers, quantum computing has great potential to improve information security, simulation of complex systems, and foster educational innovation. Engaging with these challenges will be crucial to integrating quantum computing into the educational domain.

Keywords: Quantum Computing, Education, Impact, Advantage, Challenges.

1 Introduction

Quantum computing has emerged as a popular area of study that makes use of fundamental concepts from quantum mechanics, such as superposition, but it also faces many obstacles, including restricted access to quantum technologies, the requirement for teachers to receive specialized training, and the need to modify school curricula.

But quantum computing's applications in education are also diverse, such as increasing information security, simulating and modeling complex systems, or fostering innovation (Uvarajan, 2024) (Calef,

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2025). In short, quantum computing is a transformative technology for education, but it also presents challenges and opportunities that need to be addressed (Zadeh & Khalili, 2015) (Gunalan et al, 2023).

Not only could this help educational change, but it can also address the social and organizational complexity that such reconciliation presupposes. It would facilitate a more holistic approach that goes beyond technical aspects, considering human and organizational dynamics in the transition toward an education that incorporates revolutionary quantum computing (Xiang et al., 2023) (Rahim, 2024).

Driven by realistic approaches, virtual education has also seen significant growth. Although it existed before the pandemic, COVID-19 accelerated its adoption, transforming the way students around the world learn. Virtual education is a formal educational model in which teachers and students interact remotely, without the need to be physically present, using virtual platforms. Students access educational resources through channels such as email or radio. In addition, they take responsibility for their learning autonomously, under the guidance of a teacher (Bonnet et al., 2024).

However, virtual education not only created limitations in the interaction between teachers and students but also brought innovations that boosted educational progress as we knew it. Online education is the most modern version of distance education and aims to improve and facilitate access to educational opportunities. In addition to offering greater accessibility, it stands out for its interaction. Unlike conventional distance education, teachers can interact with students both synchronously and asynchronously, enriching the learning process. (Genc et al., 2022).

2 Methodology

We will utilize Kitchenham and Charters' method, which has three essential steps, in our system review:

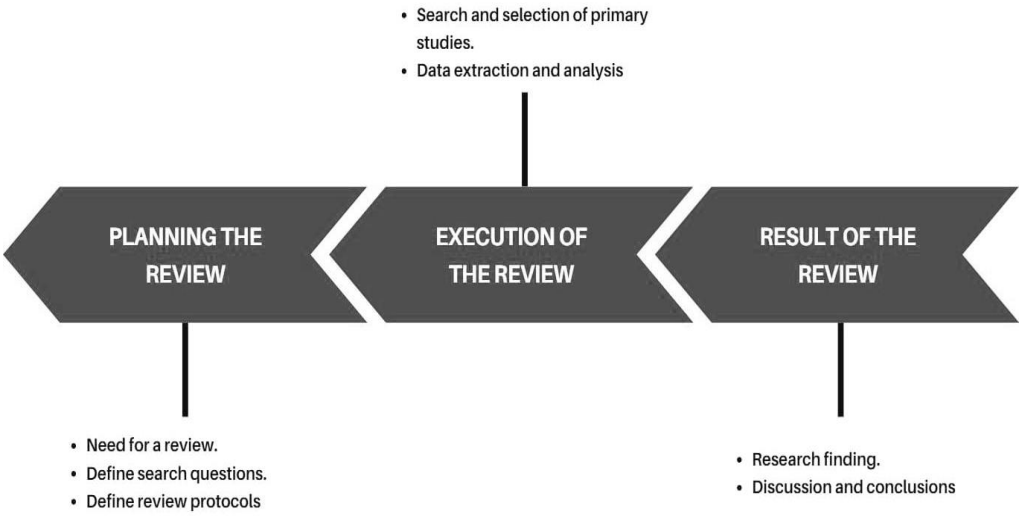

Figure 1: Systemic Review Process

Planning the review. This involves understanding the evidence from previous readings to determine whether the experiences are favorable or what is the most appropriate approach to achieve positive results. In short, this stage tells us how to gather effective methods to analyze primary research.

Conducting the review. Primary studies are searched for and selected. These studies may sometimes be duplicated or irrelevant, but they provide an overview of the set of terms that could be most beneficial for conducting more effective searches.

Review outcomes as well as the articles' statistics and analysis are presented, as well as an examination of the research findings. These elements converge in a discussion and conclusions derived from the findings.

A. Review Planning

To establish a proper understanding of the application of quantum computing in the educational sector, to estimate whether these practices have been authentic, or for identifying the best practices and frameworks to obtain positive results, it is necessary to rely on the most solid evidence available in the virtual education literature on the use of this approach. Consequently, the process of structuring the systematic review facilitates the various procedures to compile and distinguish the main research.

Multiple scientific articles were searched in prestigious repositories such as EBSCO, ScienceDirect, Scopus, and Web of Science. In addition, a review agenda was created that identifies specific areas of research related to experiences, activities, or theories on quantum computing in virtual education. The following table shows the research questions applied for the information search:

Table 1: Search Queries on Quantum Computing

ID	Questions	Ideas
Q1	Which quantum computing studies are available in current educational system?	List the applications of quantum computers in the field of education.
Q2	Which approaches are applied to develop quantum computing in educational area?	For knowing multiple application techniques that are implemented with quantum computing in the educational sector.
T3	What are the effects of the development of the use of quantum computing in the educational sector?	Finding the first detected effects related to quantum computing in the educational sector.

B. Execution of the review

Initial Search:

Starting on November 30, 2023, the search process began by connecting similar phrases such as "quantum," "computing," "educational," and "sector" in the databases Ebsco, Scopus, Web of Science as well as ScienceDirect.

The search was expanded using the Boolean operators AND and OR, with the following initial query in the databases: ‘quantum AND computing AND educational AND sector’. These searches yielded positive results, although many studies were repetitive or of little relevance. However, overall, the results provided a more precise understanding of the key terms, which was essential for our research. In addition, they confirmed the relevance of quantum computing in the educational sector, although no previous systematic review on the topic was found.

Since the results obtained in Scopus were limited and did not seem to provide additional studies or those present in various databases, during the examination process, it was determined to eliminate additional databases.

Methodical search. The research was continued in the Web of Science, EBSCO host, and ScienceDirect databases, restricting the findings to every publication from 2018 till 2023. On the basis of experiences in the beginning, combinations of words which gave optimal outcomes in these databases had been identified and are described below:

Table 2: Quantum Computing Search String

Questions	Search string
Q1	Quantum AND computing AND educational AND sector
Q2	Quantum AND computing AND methods AND educational
Q3	Quantum AND computing AND impact AND educational

Criteria for exclusion

The articles were filtered using the criteria given below:

Table 3: Search Criteria

Criteria for exclusion
Articles that don't fit the requirements for inclusion.
Documents that are not articles that are under review or do not have open access were excluded.
Articles that were unrelated to the application of quantum computing in educational aspects were discarded.

Extra Filters:

More intricate application of filters will be done for refining articles selection

Filter one:

It will contain a thorough reading and review of the title and summary of each article.

Filter two:

It will focus on removing any duplicate articles found in other databases.

Once these filters have been completed, the articles obtained by the snowball method will be included and selected based on their references and their ability to provide relevant content to the systematic review, provided that they have passed the initial search stage.

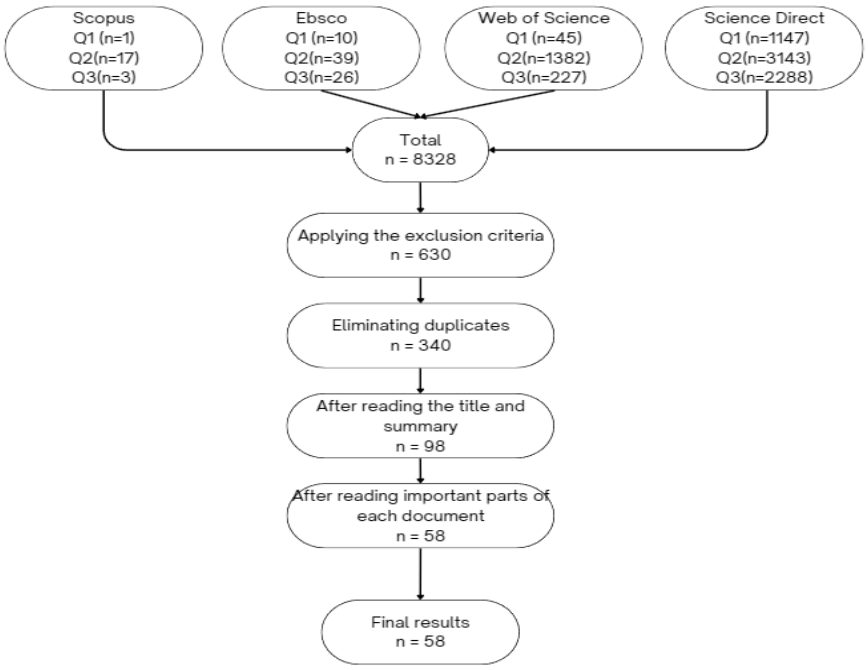

Figure 2: Article Search Process

After finding a total of 8328 articles, criteria of exclusion as well as inclusion had been executed for selecting the relevant ones in Figure 2. A procedure of screening had then been carried out using more specific filters, incorporating articles that emerged during the procedure of reviewing. Consequently, 58 main studies were acquired.

Review Outcome

Following the analytical search, the results are presented in Table 4, which summarizes the technologies and strategies used to facilitate the integration of quantum computing in education, as well as its impact on the academic field (Sathish Kumar et al., 2024). The analysis of the studies reveals varied approaches to the application of quantum computing in teaching. Some studies highlight its ability to improve the resolution of complex problems, while others underline the potential to personalize learning. Overall, these advances have been fundamental for the development of new educational methodologies (Tukur et al., 2024).

3 RESULTS

Q1. What Studies Exist on Quantum Computing in the Educational Sector?

Table 4: Results Related to Question 1

Qualification	Author's contribution
Educational resources to foster talent in quantum computing	Pashaei et al. (2020) stated that quantum physics has strongly impacted the economy, especially in areas such as chemistry and electronics. With the increasing relevance of Quantum Computing in industry, there is a need to prepare the workforce from an early stage. However, complexity often limits the exposure of younger students. We propose to integrate quantum computing concepts into primary and secondary education, supported by resources tested in real classrooms. This seeks to foster the interest and preparation of future professionals in this field.
Proceedings of the 32nd International Convention: Informatics in Education	Information and communication technologies, microelectronics as well as electronics are the subjects of 315 papers in the 32nd International Convention Proceedings: Computers in Education (2009). Subjects covered range from the semiconductor industry to the application of technologies in education. The conference highlights the need to integrate quantum computing into education, proposing classroom-tested resources to address the complexity and foster interest from the earliest stages of primary and secondary education.
Using mathematics to support transdisciplinary STEM education for future-proof quantum algorithmic literacy	According to How (2022), people believe maths is hard. Even though mathematics is crucial to STEM education, this belief has endured. In the context of quantum technologies, which impact several industries, there is a need for business and public leaders to become knowledgeable in quantum computing (Gasca-Hurtado et al., 2018). The proposal aims to address mathematics aversion through algorithmic literacy, presenting information in an understandable way to engage people and improve their understanding. Entanglement, also quantum cryptography as well as linear transformations are

	among the ideas covered in mathematical introduction required for explaining quantum computing. The usefulness of these ideas is demonstrated using the example of teleportation. Algorithmic literacy not only reinvigorates interest in mathematics but also provides an analytical framework for teachers to address individual student needs and dispel any uncertainty about mathematical concepts.
What knowledge of quantum physics is necessary for students studying quantum computing?	Bungum and Selsto (2022) point out that quantum computing is evolving rapidly and specialists from this sector are urgently needed. But a dearth in tradition on how to teach quantum physics to IT students with no prior physics experience is prevalent. This article proposes key topics for a master's course in IT, ranging from fundamental concepts of quantum physics to their coding as well as algorithm application. The suggested framework is based on one course started at Oslo Metropolitan University, Norway. Results from interviews and questionnaires show that students are keen in improving their quantum physics knowledge for quantum computing, and an integrated approach works well for most, although some encounter challenges that require clarification of the objectives of each course component.
Proceedings of the 32nd International Convention: Intelligent and Technical Systems Using Computers	Information and Communication Technologies, Microelectronics as well as electronics are the subjects of 315 papers, according to the 32nd International Convention Proceedings: Computers in Technical Systems and Intelligent Systems (2009). Various subjects have been discussed, such as rare earth-activated nanostructures, applications in THz research, electrical activation of phosphorus, Raman scattering on porous silicon, and modeling of radical effects in plasmas for etching in microelectronics, among others. Areas such as control systems, wireless networks, simulation, algorithms, wireless access technologies, distributed memory management, and various educational approaches, from online teaching to the development of learning support systems, are also covered.
Proceedings of the 32nd International Convention on Telecommunications and Information	Proceedings of the 32nd International Convention: Telecommunications and Information (2009). The text addresses a wide variety of topics in Information and Communications Technologies, Electronics, and Microelectronics. Semiconductors, rare earth-activated nanostructures, the research, electrical activation of phosphors, optical devices, sensors, algorithms, and control systems in various applications. The curriculum also includes educational topics such as the integration of technologies in education and the creation of systems to facilitate learning. It covers various subjects, both theoretical as well as research elements for practical implementations in various fields.
Cloud-based educational support and hybrid quantum neural network algorithm-based evaluation of the quality of education	To enhance resource allocation and quality evaluation, Xiang et al. (2023) created a model for an advanced education system that used a hybrid quantum neural network method. This innovative algorithm fuses quantum computing with networks,

	making it well-suited to manage complex tasks within the education industry. Furthermore, the algorithm is used to address resource allocation challenges in green supply chain management, leading to increased sustainability and cost reduction (Pashaei et al., 2023). Research findings indicate that this model significantly improves the effectiveness and accuracy of assessments and resource allocation, thus playing a role in building a more sustainable future.
Computer science-based strategy for reaching different audience with quantum computing	According to Salehi et al. (2021), by approaching quantum computing in a way in which an extended probability theory rather than a solely physical sector, this study provides an alternate pedagogical way to teaching it to a wider audience. facilitating learning through the use of quantum programming as a teaching technique. The aim is to raise awareness of this initiative among academics and organizations that want to make quantum computing accessible to people from different backgrounds. The course design skips the introduction to quantum physics and focuses on introducing the concepts through linear algebra, with quantum programming assignments designed accordingly. The findings show a significant rise in participants' quantum computing knowledge and overall satisfaction with the learning process. The results are consistent regardless of the participants' STEM-related academic background.
Analysis and outlook of the latest developments in blockchain technology and applications	Gad et al. (2022) highlight that the text describes the growing importance of Blockchain technology in commerce and cryptocurrencies development like Bitcoin, based on this technology. It highlights the need for more research on Blockchain, especially since its inception in 2013. The article presents a review of the most influential literature on Blockchain until 2020, using the Web of Science Core Collection database. Several key aspects of the collected articles are discussed, such as publication and citation trends, topical research areas, and funding. The application of Blockchain in different domains is discussed and future challenges and developments are mentioned. In summary, the article aims for associating with new and experienced researchers as well as practitioners who wish to explore and design Blockchain solutions, considering current demands and challenges.
UnIC: The development of an autonomous intelligent cluster as well as its social integration	Zhang et al. (2022) propose the idea of unmanned collaborative systems, highlighting their advantages such as performance, efficiency, and flexibility, thanks to the incorporation of artificial intelligence. However, they point out that current systems have limitations in terms of applicability and satisfaction of human needs. A human-centered vision called Unmanned Intelligent Cluster (UnIC) is proposed, where systems and humans connect to achieve collaborative cognition. The concept, architecture, and technologies related to UnIC are detailed, as well as issues of social acceptance.

A taxonomy and scoping evaluation of COVID-19 macroeconomic and epidemiological models	According to Bonnet et al. (2024), the COVID-19 pandemic had a disastrous effect on both the economy and world health, with millions of deaths and a significant loss of global gross domestic product (GDP). Policy responses, including lockdowns, affected both health and the economy, with both short- and long-term consequences. Assessing health and macroeconomic outcomes, as well as potential trade-offs, requires evidence-based models. However, communication and trust in these models can be challenges, as seen in the COVID-19 response, where political processes divided epidemiological and macroeconomic models in countries such as the United Kingdom. The importance of effective cooperation between stakeholders and the need for a stricter review of the models used are highlighted.
Blockchain and IoT in medication supply management and smart cities: unresolved problems, prospects, and potential paths	Malik et al. (2023) Blockchain-based DSM (drug supply management) is believed to require a high level of security and privacy to ensure identity verification, interoperability, and medical record sharing. Conversely, smart cities (SCs) that are IoT-based have numerous smart applications that can enhance citizens lifestyle. BCT (Blockchain technology) makes SCs more secure by enabling tracking of transactions on an immutable and decentralized ledger. More generally, the intention of this work is to consider which BCTs and IoT are currently used particularly in DSMs and SCs and review the current body of research ISSN: Page 2/15DOI:10. Search criteria will be systematically performed on various databases using specific keywords. These papers are categorized into three groups (Design as well as development of DSM and SC applications embedding BCT and IoT; Scientific study of usage of BCT and IoT within DSM and SC; Examination of the integration of DM and BM while enabling use of BTS technology). This study highlights the rationale for fostering IoT as well as BCT in DSM as well as raises unresolved issues along with recommendations. It familiarizes DSM researchers with alternatives and points out relevant research areas leading to more decentralized applications.
Recent advances in chiral absorbent metamaterials	Ashalley et al. (2021) in the past few years, studies on chiral metamaterial absorbers (CMMAs) have gained momentum. These advanced materials are skillful at suppressingradiation transmission and show distinct optical properties in the presence of right- and left-circularly polarized light (LCP, RCP). CMMA is suitable for a wide range of specialist applications due to its outstanding chiral optical properties, proven production techniques, and interference in different physical, chemical, and biomolecular systems. This review delves into the theoretical foundations, design methodologies, and fabrication techniques associated with CMMA. We emphasize both traditional fabrication approaches and state-of-the-art optimization strategies that leverage algorithms and machine learning. Additionally, we explore a variety of

	applications of CMMA, including enantioselective photodetection, chiral imaging, and hot electron generation.
Connectivism and leadership: drawing on a theory of learning for the information age to redefine leadership in the 21st century	Corbett and Spinello's (2020) article serves as a comprehensive review of connectionism, a learning theory predominantly used in digital contexts. It delves into the application of connectionism within leadership, proposing new perspectives for understanding and practicing leadership in the modern era. The aim is to connect the impact of digital learning in education to management practices, employing connectivism principles to inspire conversations about innovative management strategies.
Quantum physics in space	Belenchia et al. (2022) point out that advances in quantum technology are transforming physics research and promising innovative technological applications. Recent missions using quantum technologies have achieved surprising results that highlight the potential of the space environment for the use of these technologies. This review focuses on the integration of quantum physics with space applications to address fundamental scientific questions as well as potential academic and commercial applications.
A closer examination of cybersecurity challenges during the Covid-19 pandemic: a survey	Alawida et al. (2022) it should be noted that this study examines the rise in cybercrime during the COVID-19 crisis and highlights several cyberattacks across the globe. The frequency of these attacks has increased significantly over time. The 15 most common types of cyberattacks are identified and their devastating impact during a pandemic is analyzed. This article provides a detailed overview of the major cybersecurity challenges faced by organizations and suggested solutions. Using qualitative methods, data from a global survey was collected between March 2020 and December 2021. It highlights the need for governments and organizations to remain resilient and innovative in cybersecurity to meet current and future challenges. The findings of the study guide designing and implementing stronger security systems to protect people from future cyberattacks.
A vision of artificial intelligence for 6G communication	Ahammed et al. (2023) 6G communication networks are expected to be a revolutionary innovation with a “sixth sense” and enable the operation of the Smart Internet of Things. This technology, in conjunction with artificial intelligence, is set to open up new opportunities, including enhancing human intelligence, interconnecting various systems, and elevating the quality of life. The article highlights the crucial role that artificial intelligence plays in advancing 6G communication technologies, particularly in developing applications tailored to human needs and technologies that enhance the value of these emerging innovations.
A study of machine learning's application in materials research	Mubarak et al. (2023) in this work, as presented in a recent comprehensive review, different ways of using machine learning methods for materials science problems are discussed and their positions across six vital domain dimensions were demonstrated. In fields ranging from materials science to

	image processing, machine learning is revolutionizing the way we extract knowledge and process information. Machine learning can drive discovery by predicting patterns and structure-property relationships, enabling targeted design. Additionally, it offers precise atomic-level property prediction and enhances the precision of object recognition and categorization in image processing. Machine learning has the potential to revolutionize materials research by speeding up discovery, enhancing performance, and spurring innovation—despite obstacles like data quality and algorithmic complexity.
Cybersecurity: current state, obstacles, and potential paths	Admass et al. (2024) discuss how cybersecurity is becoming critical in an increasingly digital world and needs the attention of researchers and organizations. This article provides an overview of the current cybersecurity landscape and discusses global challenges, strategies, and trends. Through a systematic review, we explore the latest trends and propose future strategies to combat rising cyber threats, also the utilization of ML and AI. The importance of continued collaboration among cybersecurity stakeholders was highlighted.
Web3: A thorough summary of the history, applications, technology, zero-trust architectures, difficulties, and potential paths	Ray (2023) observes that Web3, the future of the Internet, aims to provide a decentralized and democratized platform where users can own their online data and identities. Yet, it is challenged by scalability, interoperability, regulation, and energy consumption. This article thoroughly examines Web3, discussing its developments, implications, and major applications like DApps, DeFi, NFTs, DAOs, and supply chain monitoring. It also discusses its social and economic potential, as well as its convergence with new technologies like AI, IoT, and smart cities. The significance of zero-trust architecture for Web3 is emphasized. In conclusion, the review emphasizes how Web3 applies to the transformation of the Internet and identifies impending challenges and prospects.

Table 5: Studies on Quantum Computing in the Educational Sector.

Area	Related studies
Pedagogy	How (2022), Bungum and Selsto (2022), Xiang et al. (2023), Salehi et al. (2021), Corbett and Spinello, (2020).
Diversity in education	Pashaei et al. (2020), Proceedings of the 32nd International Convention: Computers in Education (2009), Gad et al. (2022), Belenchia et al. (2022), Mobarak et al. (2023).
Ethical and social aspects	Zhang et al. (2022), Bonnet et al. (2024), Malik et al. (2023), Alawida et al. (2022), Admass et al. (2024)
Inclusion and diversity in education	Proceedings of the 32nd International Convention: Computers in Technical Systems and Intelligent Systems (2009), Proceedings of the 32nd International Convention: Telecommunications and Information (2009), Ashley et al. (2021), Ahammed et al. (2023), Ray (2023)

For a better understanding of the above table, Figure 3 shows the results:

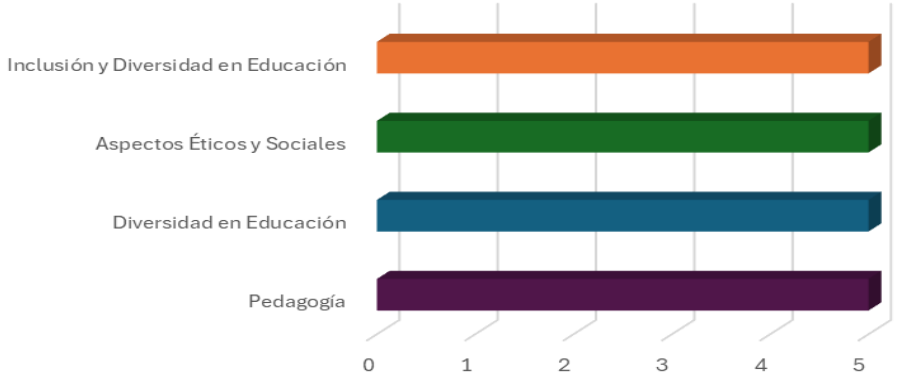

Figure 3: Number of Studies by Area

Relevance

The analysis of the studies reveals a notable dominance of Pedagogy, which represents 33.33% of the study of applying quantum computing in the educational sector. It is closely followed by the area of Ethical and Social Aspects, also with 33.33%. In contrast, Diversity in Education and Inclusion and Diversity in Education have a lower representation, with 16.67% each. Although these percentages are lower, it is important not to underestimate them, as they also present valuable opportunities. In short, there is a diversified interest in the feasible quantum computing implementations like Pedagogy as well as Ethical and Social Aspects, suggesting a change in the way of facing current challenges.

Comparison

Pashaei et al. (2020) highlight the relevance of quantum computing in various educational areas. They mention its application in data exploration in vast repositories, development of educational resources, teacher training, learning assessment, and teaching methodologies. Furthermore, they show the significance of accessibility as well as equity in quantum education.

Xiang et al., (2023) highlight the need to explore the intersection between quantum computing and machine learning in the educational field. They point out that the rapid growth of data can exceed the capacity of conventional learning algorithms. In this context, quantum computing is presented as an agile solution to process large volumes of information.

Q2. What methods are used in quantum computing enhancement in education sector?

Table 6: Results Related to Question 2

Qualification	Author's contribution
Computationally integrated design within additive manufacturing via topology optimization integrated with Multiphysics multiscale materials and process modeling	Bayat et al., (2023) tell us that additive manufacturing (AM) processes have been used in conjunction with topology optimization (TO) to create complex geometries. However, defects can arise during manufacturing because TO does not consider process constraints. Advanced AM process simulations can predict these defects, but traditionally, TO and process simulations have been considered separate paradigms. This research seeks to combine these methods into a unified computational design platform. The literature on TO is reviewed and contemporary physics-based TO methods pertinent to AM are investigated. Procedure simulations, including metallic and non-metallic additive manufacturing, are considered essential. Multiscale techniques for materials and processes are also discussed. The article concludes with suggestions for future research.

Many-body quantum dynamics via variational Schrieffer-Wolff transformations	As per Wurtz et al., (2020), they offer a variational approach to computing the generator of Schrieffer-Wolff transformations from recent results on adiabatic gauge potentials. In such transformations, a Hamiltonian is block diagonalized by a unitary rotation. This process leads to computationally manageable effective dynamics in a reduced Hilbert space. These rotations' generators are computed variationally, surpassing traditional perturbative methods. In addition, the variational ansatz localization determines the error. Two models are employed to demonstrate the method. First, due to the unavoidable intermixing of different view sectors, there are signs of many-body nonlocality in the thermodynamic limit of the attractive Fermi-Hubbard model with site disorder.
Fractional Hall quantum state real-space entanglement spectra projected onto the lowest Landau level via Monte Carlo techniques.	Anand & Sreejith, (2023) mention that the real spatial entanglement spectrum (RSES) of a quantum Hall effect (QH) function reveals the excitations at the edge. Computing it becomes expensive with more particles and Landau levels. The Monte Carlo method is efficiently used for test states such as composite fermions (CF) and approximations for projection to the lowest Landau level (LLL) are studied. Results from computational simulations are compared with exact methods to validate these approximations. Accurate RSES results are presented for bosonic and fermionic states in systems of size up to N = 24 on the sphere, showing close matches between simulations and exact spectra.
Cloud-Assisted IoT Fingerprint Recognition Techniques Using Fuzzy Commitment: A Sectoral Coding Method Based on Minutiae	Shi *et al.,* (2019) argue that in cloud-based IoT aspect, security becomes critical. We propose an IoT fingerprinting method based on a fuzzy participation contract and a sector-wise encryption strategy. Our method encodes details into fingerprints that are encrypted using error codes and hash maps. This approach aims to balance security and complexity while maintaining an acceptable level of authentication and error message rejection.
In the final state at $\sqrt{s}$=13 TeV, look for new particles in an expanded Higgs sector with four b quarks.	This extends the search for the X resonance on a large scale, which further decays into a pair of spin-0 ψ bosons, which further decay into a pair of bottom quarks, as per Tumasyan et al., (2022). The analysis only covers mass ranges between 25 and 100 GeV and 1 and 3 TeV. The decay products of each ϕ boson are anticipated to coalesce into a single large-radius jet in these mass ranges. These jets are detected employing techniques for flavor and structure identification of their jets. The analysis is founded on proton-proton collision data with an integrated luminosity of 138 inverse femtobarns collected at the CERN LHC between 2016 and 2018 with the CMS detector. Where the two extra particles are from an expanded Higgs sector, model-specific limits are defined. Under the assumption that the branching fractions for ϕ and the background are 100%, this is done by computing the product of the effective production cross section and the branching fraction for X in terms of the masses of the resonances.
Low- and high-energy bounds of the fully Lorentz-violating vacuum polarization tensor	Here, complete vacuum polarization tensor is computed in the fermionic sector of quantum electrodynamics (QED) with Lorentz symmetry breaking, as Felipe et al., (2023) observe. Even under the assumption of momentum routing invariance in Feynman diagrams, we find that a definite vacuum polarization tensor cannot be achieved by removing all surface terms. The low- and high-energy limits of this tensor are unambiguously determined. Only the coefficients $c_{\mu\nu}$ enter in the high-energy limit. The terms due to Lorentz symmetry violation in the low-

	energy limit are functions of the coefficients bμ, cμν, and gμνλ, and they go to zero when p=0. Pertinent consequences for condensed matter systems, namely the Hall effect in Weyl semimetals, are considered when small values of linear momentum (p) are considered.
Corrections to the neutral Higgs boson masses in the CP-violating NMSSM using two-loop O(αt2)	In the near-standard minimum supersymmetric extension (NMSSM) context, Dao et al., (2019) offer detailed calculation of two-loop corrections to the neutral Higgs boson masses (\(H^0\)) with special focus on CP symmetry breaking. In the zero external momentum calibration-free limit, the Feynman diagrammatic approach is employed for carrying out this calculation. For NMSSM input parameters, there is a mixed \(\\overline{\\text{MS}}\} cascade renormalization approach applied, while both \(\\overline{\\text{MS}}\} and cascade renormalization are employed within the top/stop quark sector. Both the conservative and CP-violating cases of the Higgs spectrum at NMSSM are numerically calculated by using the Fortran program NMSSMCALC, in which the corrections discovered are included. Data on decays of Higgs bosons, including higher-order corrections, are also given by this code. These improvements are seen to be better than those which exist already within NMSSMCALC, varying from two-loop improvements \((\alpha_t \alpha_s)\) in the gaugeless limit with zero external momentum to full one-loop improvements without approximation. Corrections of order O(\(\\(\\alpha_t \\alpha_s + \\text{OS})) are observed to increase the mass in a Higgs boson loop by approximately 4-7%, similar to the Standard Model (\(H^0\)), when considering renormalization within the top/stop quark sector, as a function of the parameter point. Also, if \(\\text{OS}) renormalization is applied, such corrections decrease the mass by approximately 6–9%. A renormalization scale and new renormalization methods are employed to estimate the theoretical uncertainty, requiring special care in the related interpretation.
Search for new jet decay particles and an emerging jet.	Sirunyan et al., (2019) are searching for the coupled synthesis of a new heavy particle that acts as a bridge between a dark sector and regular matter, decomposing into a new, light quark and a recently discovered fermion called a dark quark. A 2016 CMS detector measurement of an integrated luminosity of 16.1 fb-1 for proton-proton collisions at 13 TeV at the CERN LHC was found using the data from this search. A dark quark, which is only charged under a new force similar to quantum chromodynamics, creates a "pop-out jet". Through a shower of patterns with long-lived dark hadrons, this mechanism transfers vertices from the decays into Standard Model hadrons. The measured data are in good agreement with the Standard Model's process predictions. The 95% confidence bounds do not include dark pion decay lengths of 5-225 mm for dark mediators with masses between 400 and 1250 GeV. Moreover, decay lengths shorter than 5 mm and longer than 225 mm are excluded at the lower limit of this mass range. Note that the bound dependency on the dark pion mass is small for masses in the range of 1 GeV to 10 GeV. The pair production of a rising jet and an uncommon particle decaying to a jet is being searched for for the first time independently.
Search for the resonant production of strongly coupled dark matter in proton-proton collisions at 13 TeV.	Tumasyan et al., (2022) claim to show the first search for dark matter from a densely linked hidden sector using a data sample corresponding to 138 fb-1, obtained by the CMS detector at the CERN LHC at a center-of-mass energy of 13 TeV. The hypothesis states that this dark sector is connected

	to the Standard Model (SM) by a heavy Z' leptophobic mediator, which is formed as a resonance in proton-proton collisions. The mediator decays to produce two "semi-visible jets" of visible and unseen dark matter. The final state thus consists of a tiny missing energy linked to one of the jets, the characteristic that most dark matter searches overlook. There is no organization in the transverse dijet mass spectra that would be predicted given the signal. Assuming that Z' boson has a universal coupling of 0.25 to SM quarks, a model-independent search, applicable to any model with comparable kinematical behavior, excludes mediator masses of 1.5 to 4.0 TeV with a 95% confidence level based on other signal model properties. An ideal decision tree (BDT) trained with jet substructure variables is used to boost the search sensitivity for this particular class of hidden sector models. This enables the separation of semi-visible jets from background process SM jets. Using the BDT to categorize all jets in the Dijet system as semi-visible eliminates mediator masses up to 5.1 TeV for broader ranges of the other parameters of signal models. Widely dispersed models of the highly interconnected hidden sector are excluded for the first time by these limitations.
Effects of strain on the phononic and electrical characteristics of 2H and 1T monolayer MoS2	First-principles calculations were conducted on the 2H and 1T phases of monolayers of MoS2, as reported by Chaudhuri et al., (2023). We compare the relative stability of the two phases and examine the impact of strain on their electronic and phononic properties. A direct-to-indirect band gap transition and band gap reduction, which results in a semiconductor-to-metal transition, are witnessed in the 2H phase. The semimetallic state of the 1T phase is eliminated through the voltage application. We find very high strain-induced variation in frequency and dispersion of phonon branches. As we increase the strain, the ZA mode, which is an out-of-plane acoustic, is rendered fictitious, pointing to the initiation of a phase transformation or structural instability. The 2H phase exhibits a greater degree of stability than that of the 1T phase by resisting more strain. It is emphasized that how crucial anisotropic strain engineering is to change the electric and phononic properties of the MoS2 monolayer for the 1T phase and the stability limit.
Crystal symmetry protection for the semimetallic state of the topological nodal line in ZrSiS is demonstrated experimentally.	As per Gu et al., (2019), tunable symmetry breaking is vital for the control of the topological phase of quantum matter. Experimental evidence for a pressure-induced topological phase transition in the nodal semimetal ZrSiS is presented here using a combination of high-pressure magneto transport, Raman spectroscopy, and X-ray diffraction experiments. This topological phase transition under pressure is due to subtle distortions of the crystal lattice by non-hydrostatic compression, which shatters multiple crystal symmetries, including mirror and inversion symmetries, based on symmetry analysis and first-principles calculations. The core concept of topological relativistic fermion physics, protection of crystal symmetry in the topological semimetal state, is explicitly proven experimentally by this work.
In proton-proton collisions at $\sqrt{s}$=13 TeV, look for top squarks in final states with multiple light-flavored jets and two top quarks.	Sirunyan et al., (2021) inform us that a search for new physics in two top quark and extra jets events was conducted. This research analyzes events with a minimum of seven jets and a single electron or muon, with no particular limits set for missing energy. With the help of high-energy collision data obtained by the LHC's CMS detector, masses of particles known as top squarks have been ruled out in some cases, ranging up to 670

	or 870 GeV, depending on the model, with a confidence level of 95%. This research gives details about the existence of exotic particles that may be present according to physical theories beyond the standard model.
Search for the leptonic flavor that violates $J/\psi \rightarrow e\mu$ decay.	As per Ablikim et al., (2023), the application of this hybrid quantum neural network approach can provide innovative solutions for the optimal resource distribution as well as enhance the effectiveness and accuracy of educational quality evaluation. The model can help improve more effective educational administration methods through the utilization of the potential of quantum computers in addressing complex problems.
Expansion of plastics recycling technologies: chemical aspects, state of the art and challenges	Li *et al.,* (2022) additive manufacturing (AM) and topology optimization (OT) are considered allies in creating complex shapes, but process limitations can lead to defects. Advanced AM simulations can predict these problems, but OT and simulations have been considered as separate approaches. The necessity of using them as a comprehensive computational design tool is addressed in this paper. The literature on OT is reviewed and current AM-related approaches are examined. Process simulations are crucial for this integration and are discussed in detail, as are multiscale techniques for materials and processes. The paper concludes with suggestions for future research.
To protect the delicate seafood business against resistant human norovirus in live shellfish, what are the current decontamination issues and possible complimentary solutions?	Rowan, (2023) notes that protecting the seafood industry is crucial due to its importance in feeding the world's growing population. However, seafood can accumulate microbial contaminants from wastewater, leading to outbreaks of human disease. Inactivating human norovirus (hNoV) in live seafood is challenging, especially since they are consumed raw or undercooked. Using seawater that is clean as well as UV disinfection will be helpful, but additional approaches will be required for the eradication of hNoV in fresh seafood. This article reviews combined treatment approaches and alternative diagnostic methods to improve virological safety. It highlights the importance of risk management planning and real-time monitoring of culture environments to address current and future challenges.
The biomass to X supply chain's digitalization frontier: opportunities or risks?	As Loy et al., (2023) point out, the need to have a green business model amidst the climate crisis has led to the consideration of the bioeconomy as an alternative, and especially in consideration of the "Biomass-to-X" approach, turning biological resources into value-added products. Limited application of the method, nonetheless, highlights just how important it is to harness digital technologies for making it profitable. From laboratory translation to manufacture to the biomanufacturing phase and supply chain management, this paper delves into the application of digital technology throughout the Biomass-to-X supply chain. In order to ease the shift to a sustainable bioeconomy, it further examines and assesses each sector's research gaps and proposes future research directions. Decision-makers concerned with this topic will be obliged to read this review.
Review of hybrid renewable energy system (HRES) sizing, optimization, control, and energy management	According to Ammari et al., (2022), the problem of intermittency in renewable energy can be solved by utilizing HRES which integrate several energy sources. This study offers a thorough analysis of current research on these systems, concentrating on four key areas: energy management, optimization, control, and sizing. To give a thorough picture of the present status of research in this area, the methodologies employed in every section are analyzed and contrasted.

Futuristic vision of the Quantum Drone Internet: Review, challenges and research agenda	Although disruptive drone technology is frequently linked to commercial delivery, Kumar et al., (2022) suggest that it has wider potential in global strategic challenges like traffic and climate change. The potential of futuristic drone-related technologies, including quantum drones as well as its internet, also a satellite constellation with it, in societally relevant fields during the quantum era is examined in this paper. It identifies novel alternative forms of use, explores implementation problems, and highlights notable benefits through suggested enhancements. It addresses how these technologies handle socio-economic concerns and future study fields.
Bioinspired artificial synapses: engineering neuromorphic computer chips with soft biomaterials	Ahmed, (2023) Worcester Polytechnic Institute (WPI) In a new paper, researchers at Worcester Polytechnic Institute explain "six degrees of freedom" in parallel developments related to granular flow from birth to formation of artificial synapses on neuromorphic chips. The paper shows that biomaterials can replicate dynamic behaviors of biological synapses and as such could help enhance synaptic plasticity in a more energy-efficient manner. Processes such as ink printing and electrochemical deposition have been reported to develop intricate artificial synapses. Furthermore, research on potential applications in robotics, prosthetics, and cognitive data processing is still ongoing. In conclusion, the considerable benefits of the ability to incorporate soft biomaterials into artificial synapses have opened new avenues for intelligent and energy-efficient computing systems that can revolutionize current computing paradigms.

Table 7: Implications for the Educational Field of the Methods Employed in Creating Quantum Computers.

Area	Related studies
Quantum physics	Bayat et al., (2023), Tumasyan et al., (2022), Felipe et al., (2023), Dao et al., (2019), Sirunyan et al., (2019), Tumasyan et al., (2022), Chaudhuri et al., (2023), Gu et al., (2019), Sirunyan et al., (2021)
Use of biomaterials	Ahmed, (2023), Rowan, (2023)
Hardware engineering	Shi et al., (2019), Loy et al., (2023), Kumar et al., (2022)
Computer Science	Wurtz et al., (2020), Anand & Sreejith, (2023), Ablikim et al., (2023), Li et al., (2022), Ammari et al., (2022)

For comprehending the table above more efficiently, Figure 4 shows the results:

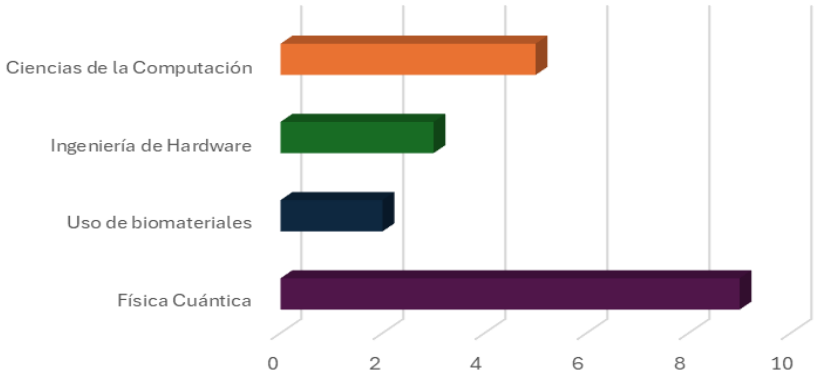

Figure 4: Number of Studies by Area

Relevance

The analysis of the studies reveals a clear predominance of Quantum Physics, which represents 47.37% of the investigation into quantum computing utilization in the educational sector. Next, Computer Science also shows a significant share, with 26.32%. On the other hand, Hardware Engineering and the Use of Biomaterials have a lower representation, with 15.79% and 10.53%, respectively. Although these latter percentages are lower, it is important not to underestimate them, as they also present valuable opportunities. In short, there is a diversified interest in the potential quantum computing implementations across different fields, especially in Quantum Physics, which suggests a change in the way of facing current challenges.

Comparison

How (2022) emphasized the significance of the convergence of machine learning and quantum computing. He stated that the explosive growth of data could overwhelm the capacity of conventional machine learning algorithms. In this context, quantum computing is presented as an agile solution to process large volumes of information. Similarly, Sirunyan et al. (2021) emphasized that this intersection offers a unique opportunity to explore and understand the fundamental principles of quantum physics in a practical setting. This allows students to study concepts such as superposition, entanglement, and coherence through quantum experiments and simulations.

Q3. What are the effects of the development of the use of quantum computing in the educational sector?

Table 8: Results Related to Question 3

Qualification	Author's contribution
An overview of fog computing: issues, traits, difficulties, and possible uses	Das & Inuwa, (2023) state that quantum computing in the education sector emerges as an innovative paradigm that adds to the evolution of previous approaches like cloud, also mobile edge computing as well as cloud computing. This revolutionary approach combines quantum principles with education, leveraging quantum processing power to deliver more efficient services, reduce barriers, and support modern education systems. In the context of the proposed taxonomy, integrating quantum computing into education involves addressing specific implementation challenges, exploring new dimensions in quantum data management, and developing strategies to optimize performance in educational settings. The difficulties and potential uses of quantum computing in education emphasize how crucial privacy and security are as well asopportunity to bring advanced quantum concepts to critical areas of education.
Creating a degree program in quantum engineering	Asfaw et al., (2022) develop guidelines for developing quantum engineering programs in the US to fulfil the increasing need for experts in the field of quantum technology. A robust framework suitable for academia was proposed following a workshop attended by 480 quantum science experts. The guide includes 1) the first introductory quantum engineering course for STEM students, 2) integrated courses in quantum engineering and STEM subjects, 3) conceptual courses for higher education institutions, 4) opportunities to address inclusion and equity, and 5) Quantum Hardware Hands-on training program. This approach aims to promote quantum engineering education and skills development to meet future industry needs.
Evaluating the quantum industry's requirements	Hughes et al., (2022) mention that quantum science and technology have advanced and are being applied in industry. A new workforce with skills in

	this field is required. Relevant jobs, skills, and titles were investigated by surveying 57 companies. A variety of job opportunities were identified, ranging from specific roles in quantum algorithms to more general categories in the hardware, software, and business domains. Furthermore, companies were found to be seeking candidates with different degree levels, from bachelor's to doctoral degrees. This knowledge informs university students, faculty, and administrators on how to best prepare the quantum workforce.
Discover the principles of quantum mechanics in an entertaining way with Quantum Tic Tac Toe.	Weingartner & Weingartner, (2023) comment that quantum mechanics is complex, but is gaining greater relevance with the advent of quantum computers. A game-based learning approach was proposed using a modified Tic Tac Toe approach. The design science inquiry technique was applied to the development and evaluation of a prototype. Reviews from users showed that this approach helped to approach quantum physics playfully and increased interest in the topic. It is suggested to continue supporting beginners during their initial training. The strategy that included a virtual opponent and compared to earlier Tic Tac Toe-based methods, the presentation of more details about the quantum circuit proved to be more successful.
An examination of the growing expectations from grant proposals from 2002 to 2020 about the societal shaping of quantum technologies	Roberson, (2021) tells us that quantum technology originated in 1990s and alludes to the application of quantum physics' characteristics. This article examines how this concept developed and became dominant in science, in particular through an analysis of Australian Research Council research funding. It highlights how expectations around "quantum technology" and "quantum computing" affect research and public perception. How we describe these technologies as "revolutionary" can significantly shape investment and research priorities. It is important to set clear expectations for this emerging field to ensure balanced and realistic progress.
Creation and application of educational resources on quantum computing for high school students: the teleportation example	Satanassi and associates, (2022) A strategy for teaching high school pupil's quantum operations is put forth in order to overcome the educational difficulties brought on by the second quantum revolution. Based on four guiding principles, this strategy seeks to maximize quantum computing's potential for education and culture. A unique aspect of the quantum teleportation protocol is highlighted to show how these concepts can be used in real-world applications. For example, imagine transferring information instantaneously between two locations without physically traveling through space between them. This demonstrates the potential of quantum technologies to revolutionize communication. High school students participated in a pilot study to assess the strategy, and while the findings are preliminary, they indicate that the strategy can foster a vibrant and inclusive society that encourages students to integrate different levels of discourse and create meaningful descriptions of phenomena. Learning environment.
Quantum game theory: a comprehensive study of AI	Ghosh, (2021) the commentary says that quantum computing has flourished in the past few decades and so has game theory, giving rise to quantum game theory. This article provides an introductory overview of research in this area, highlighting the work of several notable researchers. Quantum game theory models and their computer simulation workflows are explored, focusing on three main models: the coin-flipping game, the prisoner's dilemma, and the two-person duel. The article uses simulations performed using Python codes to analyze the differences in the behavior of classical and quantum game models.

High-performance computing's application in education	According to Serik et al., (2021), the significance of big data processing across a range of industries is driving up demand for specialists in high-performance computing. Based on the experiences of top universities worldwide, this essay explores high-performance computing education. It highlights the need for a studio-based approach to teaching in this area. Training sessions were conducted on three different types of hardware, using various algorithms and programming languages. The effectiveness of these educational methods was assessed using surveys.
Creating a quantum computer programming environment in virtual reality	According to Genc et al., (2022), quantum computing—powered by quantum physics—is quickly advancing in a number of fields, including genomics and machine learning. The development of actual quantum computers has significantly accelerated this process. These quantum computers' programming is comparable to that of the first classical computers. Among quantum computing models, quantum gates are the most common. Therefore, understanding their behavior is crucial for quantum programming. A teaching platform called QU-VR Education Tool, based on virtual reality, was developed using Unity 3D VR, inspired by other platforms such as IBM's Quantum Composer and Microsoft Quantum Katas. This study details the design process and use of this innovative VR platform.
Encrypt: A game-driven method for understanding quantum cryptography and Bell inequalities	Quantum cryptography as well as Bell inequalities are the main topics of Lopez-Incera et al.'s (2020) novel game-based approach to teaching quantum physics and its applications. Through practical exercises, this university approach gives students a first-hand look at quantum properties and their benefits. Students can simulate complex experiments such as Bell's demonstrations without the need for expensive laboratory equipment. Instead of using expensive tools, students represent quantum states and perform random measurements using dice and apps.
Future-focused science education: students' perspectives in a course on quantum computing and futuristic thinking	Rasa et al., (2022) are told that science education should address students' thinking and agency about the future to promote values, responsible science, and sustainability. We investigated how science courses affect students' perspective on the future and their ability to act. We developed a futures-inquiry-based curriculum that integrates quantum computing and future thinking in the context of global issues. The results showed that students viewed the future in a more positive, but also less predictable way, and felt more empowered to make decisions and express their career aspirations. By exploring quantum physics and embracing forward-thinking, people learn to challenge the idea of determinism and develop more creative approaches to their lives and solutions to global problems. These findings highlight the value of futures-oriented science education and underscore the importance of incorporating future thinking and proactive measures into the science curriculum.
Using quantum electrodynamics in the classroom: every avenue	Choudhary & Blair, (2021) discuss how Feynman praised quantum electrodynamics for its accuracy in explaining the interaction between light and matter. Although traditionally considered too complex for school curricula, they suggest a more accessible method using a tool called the Phase Wheel. This tool helps students understand quantum electrodynamics by visually representing the sum of all feasible routes called Feynman path integral. By combining quantum ideas with classical optics and using graphical vector summation, the Phase Wheel allows students to better understand the quantum world. For example, it can calculate the probability of a photon's path engagingly and understandably. Reach and study

	phenomena such as interference and diffraction. This method requires only basic mathematics and is suitable for high school and college students.
PySyComp: An Undergraduate Quantum Chemistry Course Symbolic Library in Python	Stippell et al., (2023) using the Python PySyComp library, developed an educational tool for advanced undergraduate training in quantum chemistry or quantum physics. This tool addresses static and time-related problems in quantum chemistry that are often neglected due to their complexity. By using quantized Hamiltonian dynamics (QHD), it captures significant quantum effects straightforwardly. Calculating basic quantum mechanical notions like wave functions, expectation values, and commutators—all essential for resolving the Heisenberg equations of motion—is made possible by the PySyComp module. This program makes complex quantum concepts more approachable and intelligible by allowing students to test basic models and investigate key ideas like zero-point energy, tunnelling, and decoherence.
Quantum literacy's potential and challenges for future learning and interdisciplinary problem-solving	Nita et al., (2023) highlight that the complexity of the mathematics involved in quantum computing limits access to this knowledge, hindering inclusive education. To address this, we proposed the concept of quantum capabilities to help a broad audience understand quantum technologies and support high-quality education in line with the UN Sustainable Development Goals. We achieve this by introducing a visual puzzle learning tool that enables non-experts to understand complex quantum operations in an intuitive yet rigorous manner. By demonstrating the red O-Mandel effect, we show how these visual tools can facilitate the understanding of complex quantum processes and promote quantum literacy. We conclude that quantum skills can overcome learning challenges and contribute to a broader and more accurate understanding of quantum computing.
Materials that are topological new quantum states in matter	Bhardwaj & Chatterjee, (2020) this paper present new topological materials that merge the electronic states of Weyl/Dirac fermions with magnetism. These materials offer a platform for exploring the principles of topological physics. Furthermore, their unique scattering properties hold promise for applications in quantum computers and spintronic devices, which could significantly advance these technologies.
Quantum Cryptography via Bit Commitment	According to Lethen, (2022), this paper explores the challenges faced by educational institutions with Bennett and Brassard's quantum key distribution protocol. To address these issues, it presents components of quantum cryptography and suggests the use of qubit commitment protocols as a solution. The paper recommends incorporating two different programming paradigms, which can serve as practical tools for fine-tuning qubits or improving computer science students' understanding of cryptographic protocols.
Educating high school pupils about quantum computing	This paper by Hughes et al., (2022) describes a successful high school subject about quantum computing for children ages 15 to 18 that attempts to close the gap between sophisticated academic books and scientific communication. The course integrates theoretical concepts with practical activities, including interactive problems and simulation labs, to encourage active learning. It is freely available under the Creative Commons license for use and download.
Endless fun on a large scale: a quantum card game	Kopf et al., (2023) told us that they are launching a card game to learn the beginnings of quantum computing strategically and entertainingly. In this game, players use state-change cards to evolve (i.e. change) from initial quantum states with various transition probabilities between them and discover the randomness, superposition, and perturbation of a quantum wave packet behind the Schrödinger equation that has a stiff sock on its old

	keyboard and dreams of the same big nightmare as classical life in HOLLYWOOD. The game seeks a novel approach to teaching quantum technology in upcoming courses.
Teaching pre-university pupils, the fundamentals of quantum information science to prepare them for the second quantum revolution	For discovering essential approaches to teach QIS (quantum information science) to preschoolers, NSF and OSTP convened a workshop titled "Key Concepts for Future Quantum Science Students" after the National Quantum Initiative Act was passed in the US (Singh et al., 2022). This aims to motivate upcoming leaders in fields including technology, communication, and quantum computing. Pre-university teachers are encouraged to create relevant curriculum materials and incorporate QIS concepts into their classes. To help students learn in this new field, a pedagogical strategy that juxtaposes classical and quantum concepts is suggested.

Table 9: Effect on Methods used in the Development of Quantum Computing in the Education Sector.

Area	**Related Studies**
Curricular innovation	Asfaw et al., (2022), Weingartner & Weingartner, (2023), Satanassi et al., (2022), López-Incera et al., (2020), Choudhary & Blair, (2021), Bhardwaj & Chatterjee, (2020)
Skill development	Das & Inuwa, (2023), Genc et al., (2022), Rasa et al., (2022), Stippell et al., (2023), Nita et al., (2023), Kopf et al., (2023)
Interdisciplinary collaboration	Serik et al., (2021), Lethen, (2022), Singh et al., (2022)
Social and ethical impact	Hughes et al., (2022), Roberson, (2021), Ghosh, (2021), Hughes et al., (2022)

For a better understanding of the above table, Figure 5 shows the results:

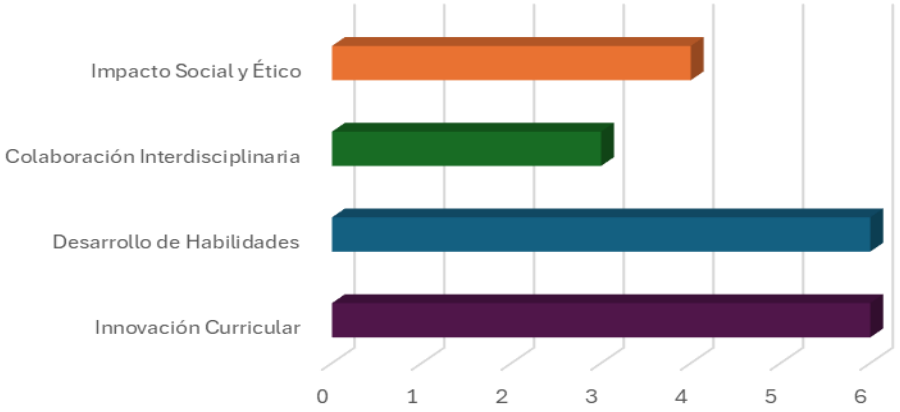

Figure 5: Number of Studies by Area

The domains of Curricular Innovation and Skills Development stand out, with 31.58% of the studies regarding the use of quantum computing in the field of education. They are closely followed by Social Impact and Ethics with 15.38%. On the other hand, Interdisciplinary Collaboration has a lower representation, with 15.79%. Although these latter percentages are lower, they should not be underestimated, as they also offer important opportunities. In short, there is a diversified interest in the potential uses of quantum computing in domains like Curricular Innovation, which suggests a change in the way of facing current challenges.

Asfaw et al., (2022) highlight that the text proposes a roadmap for developing a quantum engineering education program that meets job demands in the United States and internationally. It highlights the

importance of introductory courses in quantum engineering, specializations for STEM students, as well as an integrated quantum pathway in engineering careers. It also highlights the need to address issues of inclusion and equity in engineering and outlines plans for hands-on training in quantum hardware.

Das & Inuwa, (2023) this publication is about fog computing, an approach that brings together the benefits of cloud infrastructure and edge devices to deliver a set of higher-quality and more efficient computational services. This also helps address some of the most important operational, data management, and security issues, as well as reducing latencies and increasing mobility. It underlines the broader relevance of this model to many domains, including healthcare, urban planning, and agriculture, as well as its promise to bring substantial disruption in these areas.

Limitations Encountered and Future Research

Looking ahead, several critical areas require further attention to ensure the successful quantum computing incorporation education. A key challenge is the lack of teacher training programs tailored to this new technology. It is essential to design specialized programs that not only train teachers in the technical principles of quantum computing but also provide them with appropriate pedagogical tools to impart this knowledge effectively. Without proper training, teachers will not be able to cope with the demands of teaching such abstract concepts as superposition and quantum entanglement. In addition, the educational curriculum must be rethought, gradually integrating quantum physics concepts from the earliest levels of education. This will not only facilitate a gradual understanding but will also foster interest in emerging technologies at earlier ages, preparing new generations for the challenges of the future. A promising solution would be the development of quantum simulations in educational environments, which would make more complex concepts accessible and understandable. These interactive tools could transform the teaching of traditionally difficult subjects, allowing students to experience quantum phenomena more tangibly and dynamically. Finally, it is crucial to address the issue of equity in access to quantum technology. Educational institutions, particularly in regions with fewer resources, must be supported with programs that facilitate access to this advanced technology. This can range from government subsidies to collaborations with private technological institutions that are willing to facilitate the distribution of these tools. Knowing the above, for quantum computing to become a widespread educational resource, future research needs to focus on developing practical solutions that address teacher training, curricular innovation, quantum simulations, and equity in access to technology. These actions are crucial to guaranteeing that the educational system sees a noticeable improvement as a result of quantum computing's potential.

4 Conclusions

The analysis presented in this article demonstrates that quantum technology has enormous potential for revolutionizing education, mostly because of its sophisticated processing power and capacity to resolve intricate issues that would take more time and resources in traditional systems. The simulation of complicated systems, enhanced information security, and the development of creative learning environments are a few noteworthy quantum computing uses in education. However, along with these benefits, the study also points out several crucial issues that must be resolved in order to optimize its impact in the education sector. First, access to quantum technology is limited, especially in educational institutions with fewer resources, which restricts its large-scale implementation. Furthermore, the lack of specialized training for teachers was identified as a major obstacle, given that quantum computing is a highly advanced technical field that requires specific knowledge for its effective teaching. This challenge is aggravated by the need for a curricular reform that incorporates quantum concepts in an appropriate and structured way from the most basic levels of education. In short, while quantum

computing promises to revolutionize education and provide advanced solutions to complex problems, its adoption depends largely on the ability to overcome these challenges, both technological and pedagogical, so that students can truly take advantage of the benefits this technology offers.

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Cristhian Omar Jara Cueva, I possess a proactive attitude, a focus on organization, and a firm commitment to my responsibilities. I am enthusiastic about applying the knowledge acquired throughout my academic and professional career, and I am always willing to perform my duties diligently. Migration of database and websites between hostings. Implementation and programming in Python for an AI that understandably makes summaries. Operating system installations (Windows, Linux Destri). Creation and maintenance of web application in PHP for a hardware store.

Franklin Rodolfo Roman Nano, Professional trained in Systems Engineering, Computer Science, and Information Technology with experience in the management of E-Learning tools, design, development, management of virtual and classroom courses, analytical ability to conceptualize and integrate teams for the development of projects, adaptation to permanent changes, honesty, responsibility, self-discipline and permanent attitude to learning, currently studying a PhD in Systems Engineering at the National University Federico Villarreal.

Pablo Benites Gomez, Professional with excellent organizational skills and extensive professional experience, I have participated in projects of Analysis, Design, and Implementation of Business Intelligence Solutions (BI), as well as Management and design of the database of various BI solutions I am Professional teacher with a solid vocation. I can manage the educational plan, teach classes at the academic and social levels, and closely follow the progress of students.