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NANOTECHNOLOGY MEETS QUANTUM COMPUTING: ADVANCING QUANTUM BITS (QUBITS) AND DEVICES FOR NEXT GENERATION COMPUTING

Talha Nadeem[1], Tariq Rafique[2], Waseem Khan[3], Sahadat Khandakar[4], Ahmad Alkhayyat[5], Mahesh Lohith K S[6],Zemate Achraf Abdelghafour[7],Sedra Moulay Brahim[8]

[1]Artificial Intelligence Engineer, Department of Robotics and Intelligent Machine Engineering National University of Sciences and Technology, Islamabad,Pakistan
Email: talhanadeem496@gmail.com
[2]Lecturer Dadabhoy Institute of Higher Education, karachi, Pakistan,
Email: dr.tariq1106@gmail.com
[3]Assistant Professor, Department of Metallurgical Engineering, NED University of Engineering and Technology, Pakistan, Email: waseemkhan@neduet.edu.pk
[4]MSc in Data Analytics, Alliant International University
Email: sahadat.khandakar47@gmail.com
[5](a)Department of Computers Techniques engineering, College of technical engineering, The Islamic University, Najaf, Iraq (b)Department of Computers Techniques engineering, College of technical engineering, The Islamic University of Al Diwaniyah, Al Diwaniyah, Iraq
Email: ahmedalkhayyat85@gmail.com
[6]Associate Professor, Department of Physics, ATME College of Engineering, Mysuru, Karnataka, India, 570 028, Email: maheshlohithks@gmail.com
[7]Laboratory of Materials Physics and Subatomic, Department of Physics, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, Email:zemate.achraf@gmail.com
[8]Laboratory of Materials Physics and Subatomic, Department of Physics, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, Email:sedramyb@gmail.com

ABSTRACT:

Purpose: This work aims to understand the relevance of nanotechnology in the enhancement of quantum computing with an emphasis on the perceptions of workers in the fields. The research is going to examine the identification of these perception factors thereof by elaborating on the field of expertise of the participants of this research, their experience in the field, and their awareness of quantum bits or qubits to offer future guidelines for pertinent research and development.

Objective: The goals of this research are as follows: The first is to evaluate the present status of nanotechnology in quantum computing, second, to define the factors, which influence the professional meaning of the concept, and third, to discover the literature deficiencies. The present research also intends to provide suggestions on how interpersonal and interprofessional cooperation and research in this emerging area can be improved.

Methodology: Consequently, there was the use of a cross-sectional survey design, and participants included experts in nanotechnology, quantum computing, and related areas. The questions posed in the survey addressed respondents' experience, their view on the role of nanotechnology and their background. Data collected in this study were analyzed using the chi-square tests, ANOVA test, T-tests, correlation analysis, and regression analysis to examine the relationship between variables and determine the goodness of fit in the tests. The survey sample included 210 participants and therefore offered considerable reliability for the evaluation.

Results: The first sets of chi-square tests revealed no correlation between the field of speciality and views on nanotechnology ($\chi^2 = 14.77$, $p = 0.789$), or between their level of quip familiarity and preference for nanomaterials ($\chi^2 = 13.56$, $p = 0.631$). ANOVA test, which compared the perceived significance of nanotechnology to the years of experience, brought out an F-statistic of 0. 96 which is non-significant at $p > 0.05$ of 0. 428. The T-test of researchers' and graduate students' perception of nanotechnology showed an insignificant value at $p > 0.05$ of 1. 17. According more to the correlation analysis the results of the correlation between years of experience and perceptions of nanotechnology were non-significant ($r = -0.03$ $p = 0.664$). Years of experience and familiarity with qubits explained less than 1 % of the total explanation of the perceptions ($R^2 = 0.002$, $F = 0.22$, $p = 0.803$).

Practical Implications: Evidently, the current study established that nanotechnology is unanimously considered of extreme importance in quantum computing, to those with no experience in it, or those coming from different fields of specialty. This reflects the need for increased funding of open-ended nanoscale research and development and industries to work together as a system to solve the engineering issues that remain in communication in the development of quantum systems. The outcomes also reflect the importance of maintaining efforts in introducing nanotechnology as a part of educational programs in quantum computing so that the new generation of specialists could contribute to the development of the field. **Novelty**: Thus, this study is one of the first ones which invests empirical evidence on experts' perceptions of nanotechnology in quantum computing and involves a large and heterogeneous sample. Therefore, using a wide variety of statistical methods, the research offers a more detailed picture of factors that affect these perceptions and points to what concerns may be relevant for future studies. The results enrich the current discussion on the further evolution of quantum computing and the scientists' plans for the coming decades integrating nanotechnology into the new field.

Conclusion: The findings demonstrate a general appreciation of the significance of nanotechnology in quantum computing across scholars in the field with no variation across the fields of specialization, years of experience, or career development. At the same time, the results suggest the hypothesis that other factors influencing the perceptions remain more important than the investigated ones and are not included in this study. These results compellingly suggest that further technical research is still needed to address the barriers which limit the extension of quantum computing and help define a feasible roadmap for this disruptive technology.

KEYWORDS: Advanced Technology; Information Technology; Quantum Data Processing and Control; Human Perception; Integration and Multidisciplinary Approach; Descriptive and Inferential Statistics; Quantitative and Cross-Sectional Study; Technological Development.

INTRODUCTION:

The growth of technology has led humanity to the threshold of a different level of computing, the use of quantum mechanics and tandem with nano technology that will drastically shift the way we compute information. Another emerging computing paradigm was believed to be idealistic and is now in the process of making transition from idealistic concept to experimental realization, quantum computing which employs the concept of superposition and entanglement that are not seen in the context of classical computing. Of central importance in quantum computing is the quantum bit or qubit, an element rather different from the classical binary bit which is in either 0 or 1 state. It is this ability that shall allow quantum computers to solve problems that would take even the most advanced super computers years or maybe decades to solve. However, the application of quantum computers has come across quite a few problems mostly in the physical realization and manipulation of qubits with nanotechnology being an important factor (Finocchio et al., 2024).

Nanotechnology deals with the engineering of materials at the atomic and molecular level which is essential to construct and control the nanoscale components, which are essential in quantum computing. The combination of these two areas quantum computing and nanotechnology has given rise to different types of qubits, the ones which include superconducting circuit qubits, trapped ion qubits and semiconductor qubits where each has its strengths and weaknesses. Specific types of qubits, such as superconducting qubits, have been considered promising because of a relatively higher coherence of qubits and compatibility with semiconductor technologies. However, they are also very sensitive to the decoherence arising from the noise of the environment a challenge that researchers have been trying to tackle using better materials and fabrication processes (Gill & Buyya, 2024).

Despite recent advances and the achievements made in the creation of qubits and configuring of quantum devices, QP has several issues that may remain problematic in the future; especially the problems related to the scalability of qubits and the issue of errors. When researchers start trying to 'upscale' the quantum systems from a few qubits to the thousands or millions that are required for useful applications, issues around coherence, control and connectivity arise. Dot product retains significant degrees of error for quantum operations, and while various error correction plans have been put forward, no practical solution is known at present which scales, and which is efficient. While, for example, digital systems allow large-scale quantum computing or other quantum algorithms to be realized, the physical accommodations, such as cryogenic systems and control electronics, are also strategically challenging. These challenges point to the fact that more research and development must be done on quantum computing and nanotechnology as the two have the potential to overcome all the barriers to practical quantum computing (Khondakar, 2024).

This research gets a sense of purpose from the significance of nanotechnology in developing quantum computing, and the lack of research that addresses the questions concerning the development of quantum devices. More specifically the study aims to investigate the following research questions: how do the professionals in the field make sense of the importance of nanotechnology in quantum computing and what are the factors that influence these perceptions? This paper therefore seeks to consolidate the current information on the topic and to establish the correlation between the backgrounds, experiences and familiarities of the respondents with quantum bits to establish the current state of dissection in the field of knowledge and find out the areas that require more research and innovation (Liu et al., 2024).

The research problem of the present study lies in the question of how the theoretical advantages of quantum computing are translated into actual physical realization. It is equally well understood that quantum computers hold several theoretical advantages over classical computers in several fields including cryptography, optimization, and material science; all these are predicated upon the ability to engineer dependable and scalable quantum systems. Nanotechnology occupies the position of this effort as it offers the necessary materials and methods to construct qubits and regulate their interaction and coherence. However, relationships between nanotechnology and the mentioned challenges and the actual role of nanotechnology in addressing them have not been very clear and specified, and there remains a significant potential for further empirical research to clarify these relations and the most viable and beneficial lines for further investigation and practical applications of nanotechnology to quantum computing (Mihailescu, Nita, Marascu, & Rogobete, 2024).

In this study, the following research questions have been formulated. First of all, the conducted research aims to evaluate the state of knowledge on nanotechnology in terms of quantum computing and identify the major technological possibilities and challenges of this field. Second, the research will seek to identify the ways and means through which practising practitioners appraise and understand the uses and relevance of nanotechnology in enhancing the prospects of quantum computing. Last of all, to fill the gaps in the existing literature and suggest further improvements for the research issues that have been discussed, the study will outline further research directions for consideration (Maharjan, Wei, & Barroso, 2024).

To achieve these objectives, this study makes use of cross-sectional survey research that enables data to be gathered from a wide range of working field experts in quantum computing and nanotechnology. These questions asked for respondents' basic demographic data, years of work experience and PQ points as well as the awareness and understanding of quantum bits and the importance of nanotechnology in quantum computing. The collected data was analyzed by using chi-square tests, ANOVA, T-test, correlation analysis and regression analysis in other to provide useful information for validating or nullifying hypotheses developed to look for significant relationships between some perceived variables and the overall impression about nanotechnology in this field (Das, Palesi, Kim, & Pande, 2024).

The organization of the paper is as follows. After this introduction, the literature review highlights significant prior work available in the literature that investigates the relationship between nanotechnology and quantum computing, shortcomings of the literature as well as research that is still required. The purpose of the methodology section focuses on explaining the research plan or approach, the methods of data collection used, the methods of identification of the sample and the analysis methods used in the study, thus giving a broad view of the research process. The results section gives an account of the study and its outcomes in terms of the statistical analyses and the interpretations of the data acquired. Last, but not the least, the discussion and conclusion sections of the work bring together the outcomes of the provided analysis, lay out its implications for the fields of quantum computing and nanotechnology, and suggest further research directions (Abadal et al., 2024).

Altogether, this work fills a significant gap in the current body of knowledge dedicated to the application of nanotechnology in quantum computing, and to the employment of nanoscale materials capable of enhancing the performance of quantum computers in future ITindustries. It is hoped that by identifying what does and does not consumers find appealing about nanotechnology in the application of quantum computing, this research will help endeavours to address the practicality issues of delivering efficient quantum computing systems. Thus, the empirical discoveries of this research are expected useful to researchers, engineers, and policymakers on matters concerning the future advancement of quantum technologies and the enhancement of the performance of quantum computers (Goyal, 2024).

For additional background information, it should be noted that the field of quantum computing has come a considerable way since its early days. An early theoretical work of Richard Feynman and David Deutsch paved the way for the formulation of quantum algorithms that would be faster than classical ones. However, to implement these algorithms in practice, developments in quantum hardware were needed, which in turn had their foundation in the qubits with long coherence times and low error rates. In this respect, nanotechnology has provided several types of qubits and quantum devices that are necessary for the construction of efficient quantum computers (Khondakar & Kaushik, 2024).

Nanotechnology complements quantum computing in that quantum computing is not only applied in the fabrication of new generations of qubits but also in fashioning quantum communication devices and quantum sensors. For instance, nanomaterials have been used to create sources and detectors of photons, which are fairly important in quantum communication technology. In the same vein, there are quantum sensors that deploy quantum states' high sensitivity to external influences and have been enhanced by nanoscale precision and control. These applications show the various areas of application of nanotechnology in quantum computing and the need for more research in the two areas (Thompson).

Nevertheless, the following critical issues are yet to be addressed: Another problem within the area is in the realm of scalability of quantum computing systems. Researchers have shown qubits and quantum processors on a mini-scale but it is still a herculean task to scale up these systems to the level of demand for real-world applications. This is made worse by the fact that error correction and fault tolerance are required to deal with the fragility of quantum information in large-scale systems. Solving these problems will further call for the development of improved nanotechnology and quantum computing and an improved understanding of the factors that determine the emergence and deployment of quantum devices (Sharma, Thangam, Prasad, Dhede, & Ahmad).

To sum up, it is pertinent to stress that the present investigation attempts to address a research question that has received little attention in the prior literature – What are the impressions of hitherto unspecified working scholars from the domain of quantum computing and the sphere of nanotechnology towards the importance of nanotechnology in the development of quantum computing and information processing techniques? By comparing the results of respondents' short questionnaires regarding the basics of perception, the focal relationships predicated on respondents' background data, their work experience, and familiarity with quantum bits have been identified, and the place for further investigation has been reflected. In anticipation of the results of this study to add to the existing literature on the potentialities of quantum computing and to help in the processes of solving such issues concerning building the practical systems of quantum computing (Shaker, Al-Amiery, & Isahak, 2024).

LITERATURE REVIEW:

Nanotechnology intersected with quantum computing is one of the cutting-edge areas of present-day science and engineering with the potential for the creation of radically new technologies in the information processing, data protection and computational spheres. Quantum computing relies on nanoscale devices, and because nanotechnology is the management of artefacts at the atomic and molecular dimensions, it supplies the equipment and processes that would be essential for the construction of these devices. In this respect, quantum computing, for instance, involves the use of principles of quantum mechanics such as superposition, entangled states, and quantum tunnelling to solve more complex problems than would be possible using traditional forms of computers. Combined these two fields attracted a lot of attention of the scientific society, as these assumptions can eliminate some of the severe problems in computer science and material science. From the current Literature, there is increased research on QDs, and consequently, this field has been revealed to have the following gaps; first, the scalability of qubits, the stability of quantum states, and fabrication of logically possible quantum devices based on nanomaterials (Gramegna, Degiovanni, Calonico, Levi, & Callegaro, 2024).

The first investigations of quantum computations were concentrated on theoretical concepts and the supposed benefits of quantum algorithms relative to traditional ones. Feynman and Deutsch started developing quantum computation initially expressing the idea that a quantum system can simulate physical processes exponentially faster than the classical system. Nevertheless, these early models were mostly theoretical, and only the fundamentals of the real-world barriers to constructing a quantum computer were taken into consideration. It was only in the late 1990s and early years of the twenty-first century that experimental attempts commenced to reach theoretical constructs given the ability of nanotechnology to physically control and interrogate quantum systems as predicted and illustrated by Nielsen and Chuang (Abbas, Abdel-Ghani, & Maksymov, 2024).

The creation of qubits, the basic building blocks of quantum information, has been a major subject of this study. Qubits are similar to classical bits in some aspects and different where they can be in more than one state simultaneously due to the superposition capability, thus handling many computations at a time on a large scale. However, the identification of qubits has been potentially demanding since the physical implementation is not an easy affair. Some proposals have been made on how to physically realize qubits; superconducting circuits, trapped atomic ions, or semiconductor quantum dots. These three approaches have merits and demerits based on issues such as coherence times, error ratio and scalability (Gao, Amaratunga, Wang, & Ma, 2024).

For example, superconducting qubits have been considered as one of the most promising platforms mainly because of their reasonably long coherence times, and the use of standard semiconductor fabrication technology. Clarke and Wilhelm gave a detailed account of the superconducting qubits with special emphasis on their scalability in Clarke and Wilhelm. But they also found that the same major challenge is to sustain quantum coherence in these systems because qubits are signatory to environmental interferences and material defects. As a result, efforts continue to be made to improve the high purity of materials as well as the fabrication of qubits to reduce decoherence and enhance the performance of qubits (Kirti, 2024).

Just in parallel with the progress of experiments on SC qubits, the field of semiconductor quantum dots has advanced as well. A quantum dot is a semiconductor nanocrystal that allows for the confinement of electrons or holes with quantized states that can be employed for encoding qubit information. Loss and DiVincenzo were pioneers in pointing out that quantum dots can be used for quantum computation, although experiments have clearly shown the promise of this approach even in silicon and III-V semiconductors. Nonetheless, like other quantum computing candidates such as superconducting qubits, the prospects of quantum dots for scalability are questionable. In isolation, there is evidence that it is possible to create individual qubits that work with exceptional fidelity, but by assembling large numbers of these into a prototype quantum processor there are major technological issues to overcome especially regarding the coupling between qubits and the method of measurement of the state of the qubit(s) (El MORSALANI, 2024).

The use of nanotechnology also goes beyond the creation of qubits in the enhancement of quantum computing and into the creation of quantum communication and quantum sensors. Quantum communication is based on the use of quantum entanglement and quantum use of keys for data encryption and secure long-distance communication. In this domain, nanotechnology is used for the manufacturing of sophisticated photonic devices including single-photon sources and detectors which are extremely important for QKD protocols. Latest innovations in nanotechnology have given rise to fabrication platforms for on-chip photonic circuits with the potential for executing multifaceted quantum operations, thereby heralding the vision of large-scale quantum communication networks in Silverstone et al aspired (Thakur, Bhanarkar, Thakur, & Hedabou, 2024).

Quantum sensing another important area of application of quantum technologies also gets enhanced tremendously from nanotechnology. Quantum sensors work based on the principle that the quantum states are sensitive to the outer world perturbations; therefore, they allow measurement of even very small changes in the physical quantities like the magnetic field, electric field, and temperature. These sensors are improved for sensitivity and resolution by nanotechnology because they allow the development of nanodevices with high accuracy. For example, nitrogen-vacancy (NV) centres in diamonds are rising as strong quantum sensors sense single spins and measure magnetic fields with extremely high sensitivity. Due to the new approaches to control NV centres at the nanoscale, several applications in biology, and material science as well as advancements in fundamental physics could be made (Barral et al., 2024).

However, certain important gaps in existing literature can be noted which have to be filled. The main problem explored in the process is the issue of the scaling of quantum computing structures. Researchers have been able to demonstrate individual qubits and small-scale quantum processors but the question of scaling up remains unsolved. QC combines many thousands of qubits in an error-corrected quantum processor which has several technological difficulties such as high-fidelity, qubit control, error-correction codes and the process of cooling them up. Furthermore, so-called ‘supplementary resources’ such as dilution refrigerators and cryogenic control electronics that seem to be crucial for the practical development of large-scale quantum computing present many engineering problems that have not even been solved in principle up to date (Pregowska, Roszkiewicz, Osial, & Giersig).

A second significant research area that is not well represented in the current literature is the establishment of QCA for quantum computing with fault tolerance. Quantum systems are inextricably noisy – decoherence and other forms of ‘quantum noise’ are essential sources of errors that can contaminate quantum information destroying its intended computational content. Although several error correction schemes have been discussed and studied, integrating them and deploying them on a large scale has been a problem. More recent work has looked at the possibility of topological qubits, which are theoretically robust against some types of errors because of their non-local encodings of quantum data. But till now, the experimental studies of topological qubits are far from perfect, and many questions remain unanswered, whether this line of approach is reasonable to undertake in large-scale quantum systems (Majumdar, 2024).

The combination of nanotechnology and quantum computing also has the potential for the emergence of new materials and innovations in the physical layout of devices and systems. For example, there is research on two-dimensional materials including graphene and other transition metal dichalcogenides (TMDs) have inspired the creation of quantum appliances with new characteristics. These materials have properties which are useful for quantum applications including quantum transistors, quantum memories, and quantum sensors, as well as outstanding electronic, optical, and mechanical properties. Nevertheless, these materials are only in the experimental stage for the fabrication and incorporation into functional quantum devices and this is why further research must be conducted to fully determine their viability (Yingngam & Khang).

Moreover, there are more general, ethical and social implications to be met at each stage of developing and using information. Of all the fields, quantum computing is expected to revolutionize the cryptology and cyber security sector, pharmaceutical and chemical industries and the manufacture of new materials. Hence, attention should be paid to related concerns and prospects such as privacy security and availability. At present, there are few ethically sensitive issues raised in the available literature on quantum computing, and there is a lack of studies that consider its possible beneficial social and economic consequences. Thus, based on these gaps and challenges, the current study aims to make a research contribution to the composite area of nanotechnology and quantum computing by examining the antecedents of the extent of perceived importance of nanotechnology toward the development of quantum computing technologies (Banaeian Far & Imani Rad, 2024).

The development of this questionnaire also involves an assumption that there are general trends and gaps in the current quantum bit literature that can be isolated based on respondents' background, experience, and how often they interact with the term quantum bits. The results of this investigation will be expected to offer new research perspectives and arguments in the Q computing field that will lead to the effective creation of efficient Q computing systems. This study is specifically appropriate as innovation on both the nanoscale and the field of quantum computing is in constant progress. As the researchers proceed in their fields of choice, it is highly relevant to grasp the trends and prospects of what is to be achieved. Therefore, this author hopes to have made a useful contribution to the existing literature and the ongoing debate on one of the most promising fields in quantum computing, namely nanotechnology (Dutta & Bhuyan, 2024).

METHODOLOGY:

Using an enhanced research onion model proposed by Saunders et al, this study enrolled a thorough research methodology that was properly coordinated as follows: The research onion is very essential when it comes to the construction of research since it makes all the phases from the epistemology point to the techniques used proper and in line with the research aim. The study avoided problems associated with confusion over the method by breaking down the process into categories, where each stage of the process was necessarily determined before moving to the next level of detailed decision-making (Pulickal & D'Costa, 2024).

Finally, at the most external layer of the research onion is the research philosophy under which this research operates and adopts, positivism. Positivism is the philosophical approach that asserts that only observable factual patterns can provide legitimate knowledge; the world is comprehensible in concrete facts and figures. This philosophy was especially suitable for the present investigation as it sought to assess quotative the perceived importance of nanotechnology and how it correlates with a field of expertise, years of experience and regardless if the participant was familiar with the term 'Qubits'. Positivism influenced the decision to use the quantitative research approach because it would involve the use of quantitative data which may be quantified and easily reproduced for statistical analysis (Bagirovs, Provodin, Sipola, & Hautamäki, 2024).

Another layer that forms the second layer of the research onion is the second layer known as the deductive approach and the study embraced it beneath the philosophical layer. Deduction aims at developing a study that will fit a given hypothesis or general theory that has been formulated. Historically, theoretical frameworks were developed for this case from the literature on nanotechnology and quantum computing where there was a postulated link between background and attitude towards the application of nanotechnology. The deductive approach enabled the study to adopt these hypotheses and evaluate them rigorously in line with the available data and evidence using statistical means. It made sure that the research hypotheses were developed based on theory while at the same ensuring that the theory could be changed where necessary (Orman, 2024).

At the strategy level, the study used a cross-sectional survey which is quite appropriate for research that aims at identifying a single-time attitude, perception, or behaviour among the population of interest. This study design enabled the cross-sectional data collection to acquire data from the different sets of respondents at the same time with ease and therefore established the interdependence of different variables in the population. The use of a survey was preferred for the ease of data collection where much data could be collected in a short period because of its advantageous structure where numerous participants from different geographical locations were expected, therefore the target population included professionals, researchers and students involved in Nanotechnology, quantum computing, physics and engineering discipline (Han, Wang, & Du Wu, 2024).

That is why in the choice of methods layer quantity methods were chosen as the most suitable for answering the research questions. Qualitative approaches were not employed predominantly since this type of research focuses on the numerical values reflecting the intensity of the studied variables and the quality of the results achieved, permitting, at the same time, using statistical tests to determine the soundness and credibility of the identified outcomes. The use of a structured questionnaire in this study meant that the study collected data that could be easily quantified and this made the responses consistent hence making it easy to do the statistical analysis. The questionnaire section was divided into sections with questions that covered the demographics of the respondents and their expertise and perceptions regarding nanotechnology so that the various factors that may influence the perception of the respondents can be considered completely (Brightwood, Stephen, & Olaoye).

The last layer of the 'research onion' in terms of time horizon was used in the present study and was cross-sectional. This decision was made because the research questions were designed to evaluate the present attitudes toward the use of nanotechnology in quantum computing. This kind of study is suitable for a cross-sectional time horizon as it aims at analyzing data collected at a particular time and not over time. This approach offered a picture of the existing perception and thus helped in the identification of tendencies, which could be useful in the present technological and scientific environment (Bhagwakar, Thaker, & Joshiara, 2024).

At the core of the research onion, it is the techniques applied in data collection and analysis. For data collection, an online survey was used in this study, given the fact that it is convenient and can cover a large population. The survey was done electronically through emails and social media platforms, the participants being identified based on their interest and knowledge in the fields of nanotechnology and quantum computing. This approach was effective in ensuring that the sample used in the study was knowledgeable and up to date thus making the data collected to be credible. The questionnaire had both closed and closed-ended questions which meant that the respondents had to provide their views in the form of agreement or disagreement or their level of knowledge with certain issues (Mukherjee, Pal, Bhattacharyya, & Roy, 2024).

The total number of respondents selected for this study was 210 and the sample size was derived from both, the convenience and the statistical samples. Thus, the size of the sample used in the current study was considered to be large enough to establish the relationships between the variables of interest and at the same time feasible within the limits of the time that was available for the study. The data collection method used in this study was purposive sampling which involves choosing participants of interest in the study hence the participants had to be working in areas to do with nanotechnology and quantum computing. This was done to have participants who were conversant with the subject under study to increase the credibility of the data collected (Mooney & Williams, 2024).

In terms of age, gender, and work background, the participants were quite heterogeneous and could be found in different specializations, with different levels of seniority and working in different capacities in academic and professional environments. The participants consisted of working professionals participating in research and development in the field of nanotechnology, and graduate students and new researchers in the field. The chosen sample was diverse in terms of background and experience; thus, the research provided a perspective on how different backgrounds and experiences contribute to how participants understood the importance of nanotechnology in quantum computing (Olaoye, Gracias, & Brooklyn, 2024).

After data collection was done data was then cleaned and formatted for analysis to be done on it. This entailed looking for tick boxes that had either been left blank or filled in partially and confirming that all the collected data was in the right format for analysis. The cleaned data was then analyzed by several statistical methods, each appropriate for answering research questions or hypotheses. The first type of analysis that was used was chi-square analysis of independence which is used to compare the correlation between two variables. The chi-square test is a goodness of fit test that is used to compare the observed frequencies of the responses to the expected frequencies of the responses when the population is divided into categories. To analyze if there was a relationship between the field of expertise of the respondents and their perception towards nanotechnology and if familiarity with qubits influenced the choice of the nanomaterial for qubit development, chi-square tests were used. The findings of these tests were useful in understanding the determinants of perceptions in this area (Lončar & Pavlović, 2024).

Lastly, an ANOVA test was performed to compare the means of the groups depending on their years of experience after the chi-square tests. ANOVA is a statistical test that can be used to compare the means of two or more groups; it is a very useful tool in the hands of the researcher. To compare responses of the participants with different levels of experience ANOVA was employed to determine whether there are differences in the perception of the importance of nanotechnology. This analysis allowed for determining if the experience level influences the perception of the role of nanotechnology in quantum computing. A T-test was also conducted to compare the perceptions of two specific groups: It is suitable for researchers and graduate students. The T-test is used in the case of two independent groups to compare the means and will thereby give a clear indication of whether the two groups have a significant difference in their perceptions.

In particular, the T-test helped to determine the relationship between the role of the respondents their career stages and their attitudes towards nanotechnology. A correlation analysis was done to determine the degree and the direction of the relationship between the years of experience and the level of importance placed on nanotechnology. Correlation analysis gives us a figure that tells us the extent to which two variables are related to each other. In this study, the correlation analysis allowed us to establish whether the more experienced respondents were more likely to regard nanotechnology as important for the further development of quantum computing.

Last, multiple regression analysis was applied to estimate the level of perceived importance of nanotechnology as a function of the following predictor variables, years of work experience and familiarity with qubits (Nedjah, Raposo, & de Macedo Mourelle, 2024).

Regression analysis is a tool that is used to test the relationship between two or more variables whereby one of them is dependent. Regression analysis helped in establishing which factors influenced the respondents' perception of the place of nanotechnology in quantum computing. Therefore, this research employed a systematic approach of the research onion as the framework for conducting this research. By choosing the positivism paradigm, using the deductive approach, cross-sectional survey design and conducting a very statistical analysis, the research was very rigorous and could be replicated. Purposive sampling and the sample involved in the study were knowledgeable which helped in increasing the credibility of this study to understand the factors that shape perceptions of nanotechnology in quantum computing (Ahmad et al., 2024).

RESULTS:

To this end, the analysis conducted in this study sought to establish the relationships between the factors that make nanotechnology important for enhancing quantum computing, especially concerning qubits and other related devices. To this end, several statistical tests were used, each to examine certain correlations or contrasts in beliefs between sub-samples of the survey participants. The findings are discussed below in sequential order and are followed by tables and figures that illustrate the findings without analysis. The first set of analyses used chi-square tests of independence to determine if there was a relationship between respondents' perceptions of nanotechnology and categorical variables such as the field of expertise and familiarity with qubits. The chi-square test is one of the most important non-parametric tests that is used for testing the hypothesis of namely "there is no relationship between two variables" (Gordon, 2024).

The first chi-square test looked at whether there was a difference in how people in different fields (such as nanotechnology, quantum computing, and physics) perceived the role of nanotechnology in improving qubits and quantum devices. The chi-square test done gave a chi-square value of 14.771, with a p-value of 0.789, as indicated in Table 1. Consequently, this shows that there is no correlation between these variables at the 0. 05 level of significance. In other words, respondents across all the fields were quite convergent in their ideas concerning nanotechnology. The second chi-square test was performed to check if the level of respondents' awareness about qubits affected their perception of what nanomaterials are likely to be the most effective for the construction of qubits (Bisang et al., 2024).

The results of this study are summarized in Table 1; the chi-square statistic was 13.561 and a p-value of 0.631, implying that the awareness of qubits does not affect the choice of nanomaterial. These results are depicted in Figure 1, in terms of the bar graphs that demonstrate the distribution of responses to the items in the various categories. To some extent, this is evident from the data presented in the figure that shows the distribution of the responses of the participants by fields and level of familiarity, which appears to be relatively spread out, thus suggesting that the observed differences may have occurred by chance (Zhou et al., 2024).

Test Name	Metrics	Test Value	p-value	Interpretation
Chi-square (Field of Expertise vs Role of Nanotechnology)	Chi-square Statistic	14.771	0.789	No significant relationship between the field of expertise and the role of nanotechnology ($p > 0.05$)
Chi-square (Familiarity with Qubits vs Nanomaterials for Qubits)	Chi-square Statistic	13.561	0.631	No significant relationship between familiarity with qubits and choice of nanomaterials ($p > 0.05$)

Table 1: Chi-square Test Results

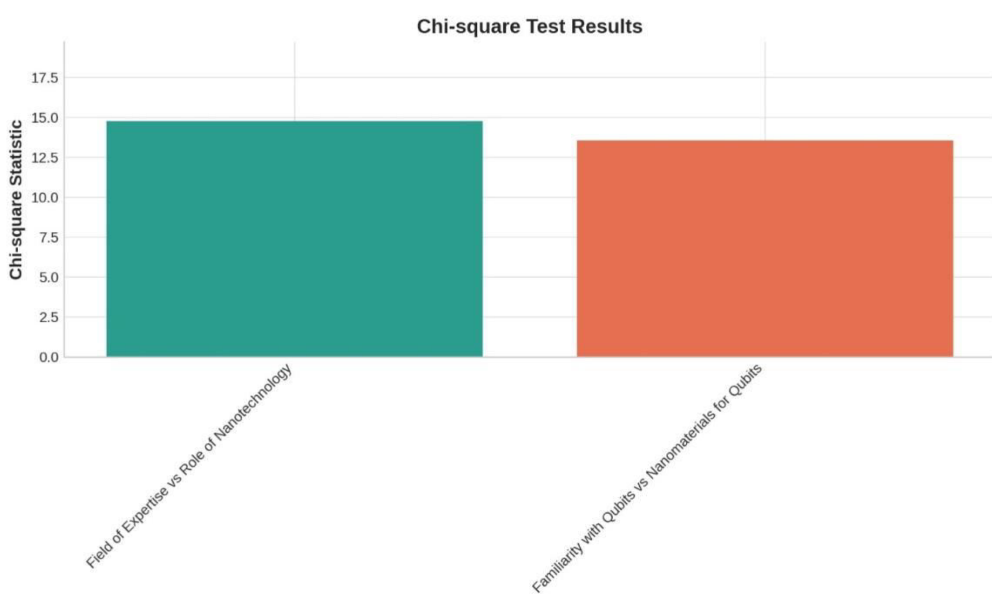


Figure 1: The chi-square statistics for the relationship between the field of expertise and the role of nanotechnology, and between familiarity with qubits and choice of nanomaterials, indicating no significant associations.

After the chi-square test, an ANOVA was used to determine whether the perceived importance of nanotechnology was a function of years in practice. ANOVA is a statistical test that is used in comparing the means of at least three populations in a bid to determine whether at least one of the means is significantly different from the others. In this study, the groups were therefore defined by the number of years of work experience of the respondents in their respective fields. The F-statistic which is another important feature of ANOVA was computed and seen to be 0. with a mean of 96 and a p value of 0. 428 as indicated in Table 2. This implies that there is not a big difference between the experienced and the inexperienced respondents in the assessment of the importance of nanotechnology in quantum computing. This can be seen in Figure 2 which shows the F statistic; there is little deviation from the null hypothesis, which assumes homogeneity of group means. This visual restates the conclusion that experience level does not hold any significant impact on the perception of nanotechnology, which is important in the understanding that regardless of the period of experience, the same impressions of the field are given (Bipin, Panigrahi, & Diniz, 2024; Kuroda, 2024).

Test Name	Metrics	Test Value	p-value	Interpretation
ANOVA (Significance of Nanotechnology by Years of Experience)	F-statistic	0.964	0.428	No significant difference in the significance of nanotechnology across different experience levels ($p > 0.05$)

Table 2: ANOVA Test Result

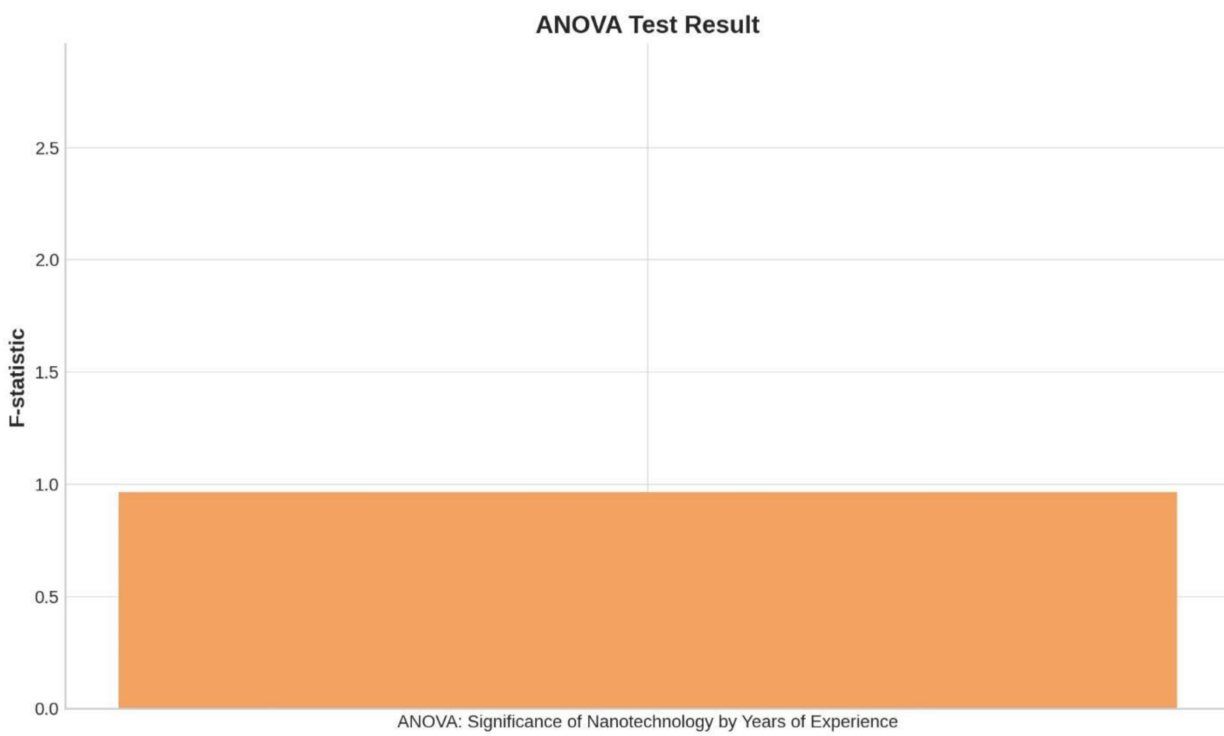
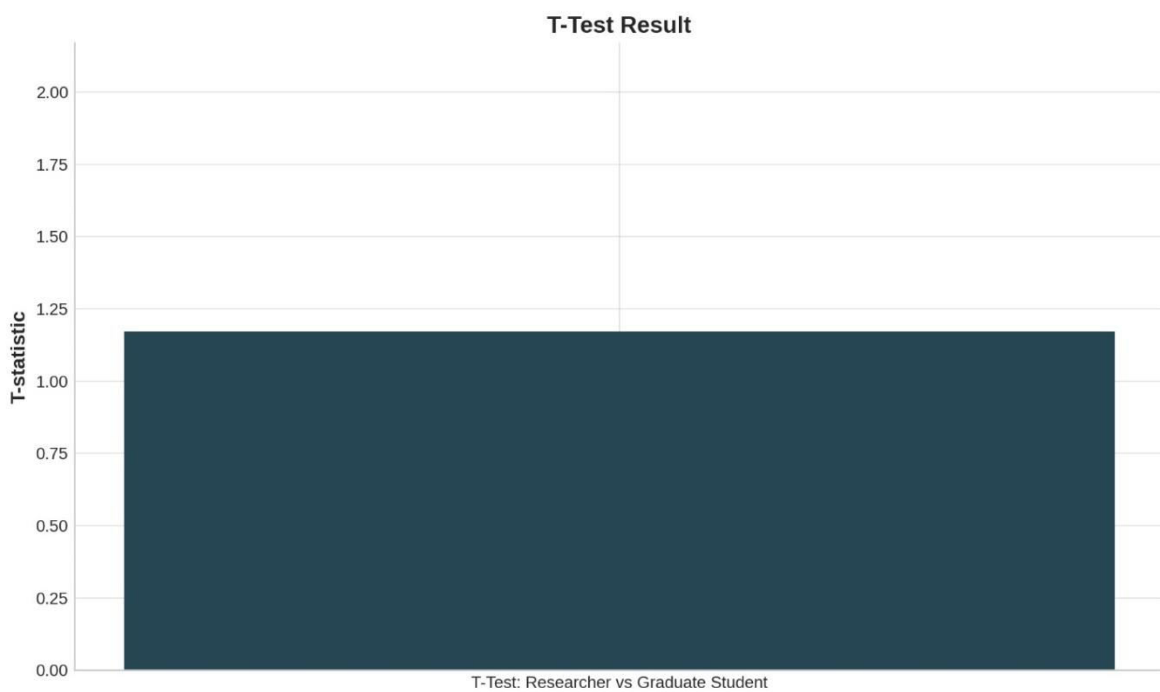


Figure 2: The F-statistic from the ANOVA test, demonstrates no significant difference in the perceived significance of nanotechnology across various levels of experience.

A T-test was also conducted to compare the perceptions of nanotechnology between two specific groups: scientists and students at the postgraduate level. The T-test is a statistical test that helps the researcher compare two or more means of independent variables to establish if there is a difference. The T-test was designed in this study to compare and contrast the perceptions that those two groups, who are in different levels of academic and professional participation in the discipline, have towards the importance of nanotechnology. Using T-Test Statistic for the given data the value was found to be 1.170 and the p-value was 0. 245 in summary form in Table 3 below. This finding shows that the two groups have equal and inconclusive perceptions. Figure 3 graphically captures this comparison, the low T-statistic indicating that both audiences' researchers who are probably more experienced in the field and graduate students who are relatively new hold similar views about the role of nanotechnology in the development of quantum computing (Xu, Su, Chai, & Li, 2024).

Test Name	Metrics	Test Value	p-value	Interpretation
T-Test (Researcher vs Graduate Student)	T-statistic	1.170	0.245	No significant difference in the significance of nanotechnology between researchers and graduate students ($p > 0.05$)

Table 3: T-Test Result



(Figure 3: T-Test Result - The T-statistic comparing the perceived significance of nanotechnology between researchers and graduate students, showing no substantial difference between these groups.)

Besides these categorical comparisons, the study also compared the two groups through a correlation analysis of the continuous variables. The hypothesis of the study therefore was; There is a correlation between the years of experience and the perception of the significance of nanotechnology. It measures the degree and direction of the relationship between two variables that are both measured on the interval scale. In this case, the correlation coefficient was calculated, and it gave a negative value of the correlation coefficient was found to be -0.030, with a p-value of 0.664, as presented in Table 4. This shows that there is a very weak relationship between the level of experience of the respondent and the importance of nanotechnology in their view. This is also evident in Figure 4, which shows the line of best fit on the scatter plot and the very low slope of this line shows that there is no relationship between these two variables at all (Budakian et al., 2024).

Test Name	Metrics	Test Value	p-value	Interpretation
Correlation (Years of Experience vs Significance of Nanotechnology)	Correlation Coefficient	-0.030	0.664	No significant correlation between years of experience and the significance of nanotechnology (p > 0.05)

Table 4: Correlation Analysis Result

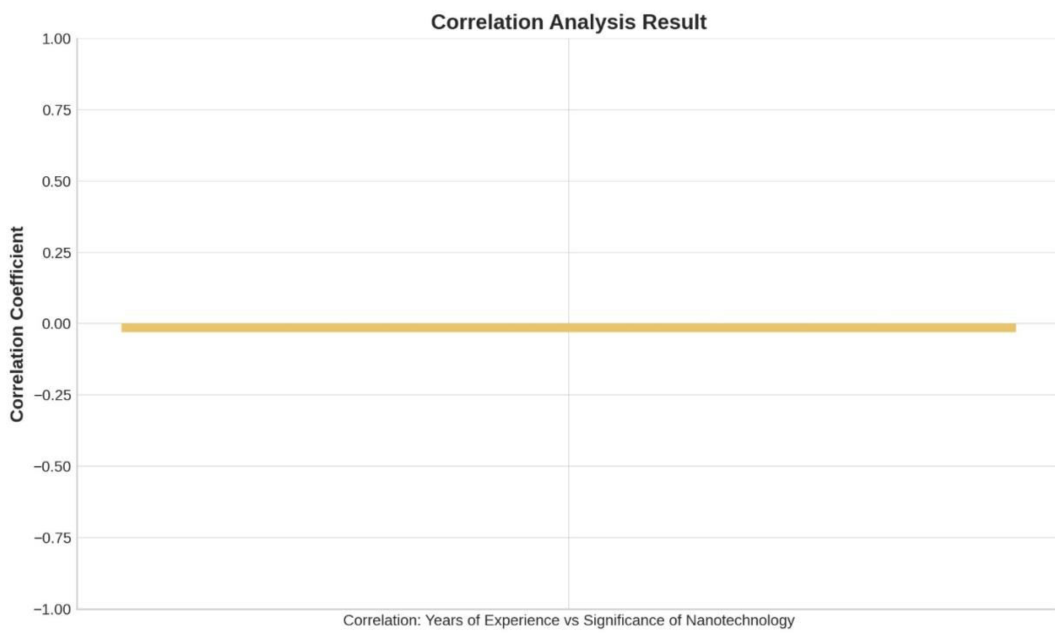


Figure 4: The correlation coefficient between years of experience and perceived significance of nanotechnology, indicating no significant linear relationship.

Finally, a regression analysis was performed to predict the perceived significance of nanotechnology based on two independent variables: The above approaches have been developed based on many years of experience and knowledge of qubits. The use of regression analysis enables one to establish the relationship between one variable that is dependent and one or more variables that are independent. Here the aim was to identify the proportion of the variance in the perceived importance of nanotechnology which could be attributed to these two variables. The dependent variable's R-square of the model was very low at 0. 002, which shows that a very small proportion of the variance in the dependent variable can be accounted for by the model. For the regression, The F-statistic was 0.22, with a p-value of 0.802, which further supports the notion that the model does not have a very good ability to account for the variability of the data. Detailed in Table 5 and depicted graphically in Figure 5 are the findings of this research. The low R-squared value as well as the high p-value indicate that years of work experience and the awareness of qubits do not seem to be good predictors of how important the respondents find nanotechnology in this regard (Pulickal, Diniz, & Panigrahi, 2024).

Test Name	Metrics	Test Value	p-value	Years of Experience Coefficient	Familiarity with Qubits Coefficient	Interpretation
Regression (Significance of Nanotechnology on Experience and Familiarity)	R-squared	0.002	0.802	-0.034	-0.003	The model explains very little variance in the significance of nanotechnology based on experience and familiarity (p > 0.05)

Table 5: Regression Analysis Summary

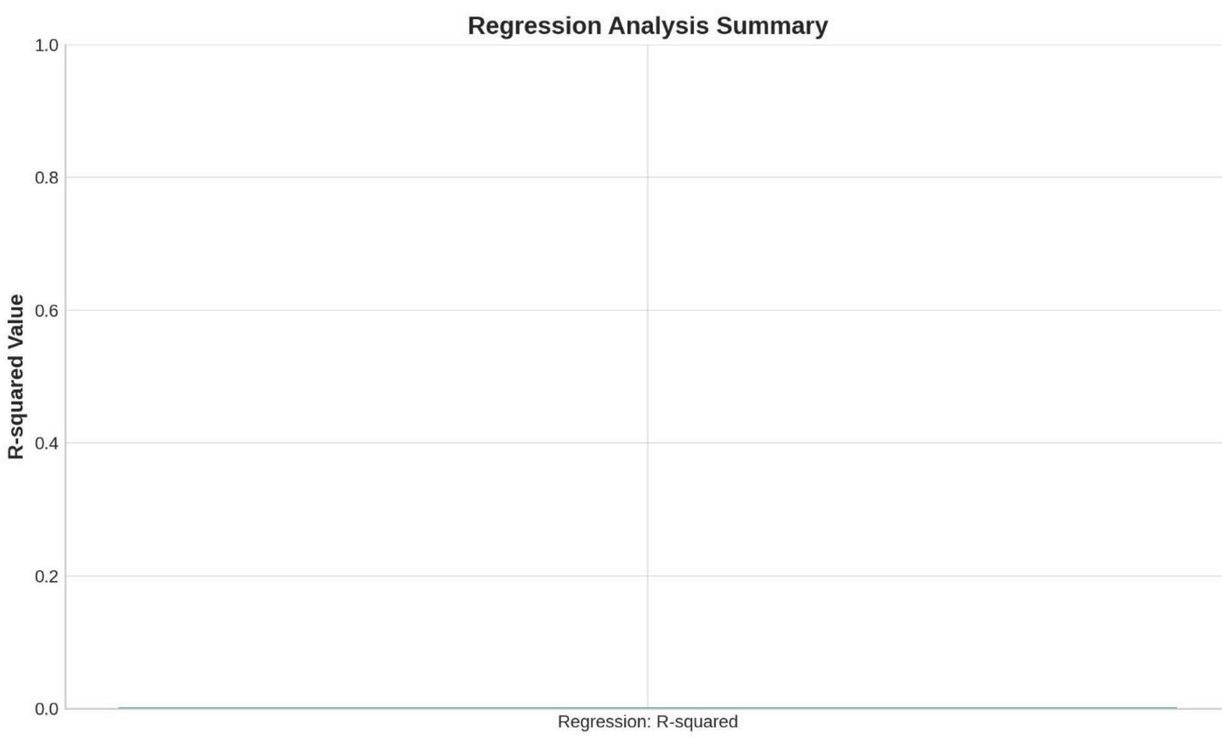


Figure 5: The R-squared value from the regression analysis, shows minimal variance explained by the model in predicting the significance of nanotechnology based on experience and familiarity with qubits.

In conclusion, all the findings from these statistical analyses also suggest that the variable's field of expertise, familiarity with qubits, years of experience, and role (researcher or graduate student) do not have any significant effect on the perception of the importance of nanotechnology in quantum computing.

When using the chi-square tests, ANOVA, T-test, correlation analysis and regression analysis, the authors find that there are no significant relationships or predictive significance of these variables. As can be seen from the corresponding figures and tables, the obtained results are quite consistent and are not greatly influenced by the variables investigated. The repeatedly non-significant outcomes in all the analyses support the idea that the attitudes towards nanotechnology as the key to the further development in quantum computing are similar across different people and within different groups, thus suggesting that the opinions are not influenced by the individual's background (O'Connor, 2024).

DISCUSSION:

This study has the following objectives in the discussion section: to explain the findings, link them to the literature, and analyze their implications for quantum computing and nanotechnology, as well as future research prospects. The findings of this study are important to understanding the beliefs of the experts about the importance of nanotechnology in the development of quantum computing and the factors that affect these beliefs as well as the opportunities and challenges that are associated with this developing field. The chi-square tests used in this study did not show any correlation between the fields of the respondents and their perception of the application of nanotechnology in quantum computing and between the awareness of the respondents on qubits and their choice of nanomaterials. These results point to the fact that the level of awareness and opinion about the role of nanotechnology in quantum computing is quite similar across different disciplines and levels of knowledge thus implying that there is a general agreement among scholars about the significance of nanotechnology in this area. This position aligns with the general literature that has time and again underscored the significance of nanotechnology in addressing the technological issues of quantum computing, especially in the design and manipulation of qubits (Fang et al., 2024; Roco, 2023).

Nevertheless, the absence of strong correlations between certain fields of expertise and the perception of nanotechnology is an intriguing question about the interdisciplinary nature of the field. It is an interdisciplinary field of study which involves knowledge in quantum mechanics, material science, electrical engineering, and computer science among other fields. It is, therefore, possible to conclude that the professionals in these various fields understand the relevance of nanotechnology even if they are not specialists in the field of nanoscopic. This may be due to two reasons: the first is the fact that nanotechnology has become an essential part of today's science and engineering; the second is the need for interdisciplinary cooperation in quantum computing. Further research could aim at understanding how interdisciplinarity affects the advancement of quantum technologies and if specific disciplinary combinations are beneficial to the advancement of this field (Srinivas & Konguvel, 2024).

The ANOVA results also provided evidence to support the concept of a common understanding of the significance of nanotechnology irrespective of the level of exposure. There was also no statistical significance of the years of experience to the perceived importance of nanotechnology to the development of quantum computing among the respondents. It is of importance, however, that both fields of nanotechnology and quantum computing have been developing at a very fast pace. That novices consider nanotechnology as important as experts show that the message about the significance of the field has been delivered and received. This also shows how well the information and education have been passed in the field as it has been able to put across the importance of incorporating nanotechnology into quantum computing studies (Kourav, Verma, Jangid, & Shah).

The T-test comparing the perception of researchers and graduate students also indicates that there was no statistical difference in the perception of the importance of Nanotechnology in quantum computing. This finding underscores the appreciation of the importance of the sub-discipline by those with numerous research publications and outputs as well as those at the beginning of their careers. This has certain consequences for the development of the field: if the current research interests of young quantum scientists and engineers are taken into account, then the future of the field looks promising. It will be imperative for this alignment to be maintained so that the advancement of the field can be sustained especially given the increasing need for personnel in quantum computing and nanotechnology (Grinin, Grinin, & Korotayev, 2024).

Correlation analysis, the connection between the years of experience and the perceived importance of nanotechnology was investigated and the results showed a near-zero correlation; this means that the level of experience does not determine the level of perceived importance that the respondents have on nanotechnology in quantum computing. This finding also adds to the understanding that nanotechnology is indeed perceived as significant across all levels of experience. However, the absence of a strong relationship also indicates that there might be other factors like the nature of research, availability of resources or exposure to inter-disciplinary work that may have a stronger influence on the participant's perception of the importance of nanotechnology. Further work could also examine these effects in greater depth and may be able to employ more detailed questionnaires or focus groups, interviews or case studies to look at how the various professions see and interact with nanotechnology in their working practices (Neyens et al., 2024).

The regression analysis, which was designed to estimate the perceived importance of the field of nanotechnology in the light of the surveyed individuals' experience in years and their acquaintance with the concept of qubits, returned a coefficient of determination of just 0. The R-squared values of 0.02 show that these variables are not very good at explaining variance in perceptions. This finding indicates that there are other factors which may be influential in the views of the professionals about the place of nanotechnology in quantum computing and which have been left out of this research. These might consist of the nature of difficulties in single subareas of quantum computing, the possibility of securing sources of finance and support, or the degree of support from institutions for work at the intersection between disciplines. The low R-squared value of the regression model shows that the determinants of perceptions of nanotechnology are not fully captured in this study and that there is a need for more elaborate studies that consider more variables (Dastgeer, Nisar, Sajjad, Jonghwa, & Kim, 2024).

To this end, it is possible to state that, while nanotechnology is acknowledged as an essential element for the creation of quantum computing throughout the literature, the strategy that is used and the concerns that are considered can differ from one case to another. For instance, the development of superconducting qubits requires nanotechnology to produce materials with low noise levels to reduce decoherence and preserve quantum coherency over a long time. On the other hand, for the semiconductor quantum dots, nanotechnology is used to have control over the size, shape as well as composition of the quantum dots to get the desired quantum behaviour. These various uses of nanotechnology are indicative of the various technical issues that exist in quantum computing, and this therefore means that a one-size-fits-all approach to the use of nanotechnology is unlikely to work (Chowdhury, Chowdhury, & Hoque).

In addition, the application of nanotechnology is not limited to the creation of qubits and concerns other aspects of quantum computing. Quantum computers need very low temperatures to work, near to zero Kelvin, to preserve the quantum state of bits or qubits. Nanotechnology plays a part in the enhancement of cryogenic systems that may attain and sustain such temperatures together with the design of nanostructures that are effective at such low temperatures. Nanotechnology in quantum computing is therefore not only in the design of qubits but also in the components that enable quantum computing. The consequences of these results are important for both the scientific world and the subject of quantum computing. First of all, the important role of nanotechnology in the recognition of nanotechnology's potential for quantum computing should remain a focus. This ranges from enhancing the materials and methods of fabrication of qubits right up to the discovery of new nanomaterials and nanostructures that could lead to better qubits or new possibilities (Bangroo, 2023).

For example, the current studies have discussed the application of two-dimensional systems, including graphene, in quantum technologies, and the findings are encouraging. Future work could therefore yield new qubit architectures or improve on the ones that are already known. Second, the absence of significant variation in the perception of quantum computing across the different fields of specialization, levels of experience, and career stages underlines the need for collaboration in the field of quantum computing. Since quantum computing is a highly interdisciplinary field that touches on areas as diverse as quantum mechanics, materials science, electrical engineering, and so on, the next step will be to ensure that there is cooperation between these various disciplines to address the various technical problems that arise in the scaling of quantum systems and the development of effective error correction strategies. Research institutions and funding organizations should keep on supporting interdisciplinary research and encourage professionals from different disciplines to collaborate in quantum computing research (Alfieri, Anantharaman, Zhang, & Jariwala, 2023).

Last, the results indicate that there is a need for further studies to establish the determinants of the perception of nanotechnology in quantum computing. However, other factors which have not been included in this study include the level of institutional support, availability of advanced equipment, and exposure to interdisciplinary research. Further studies could examine these factors using both quantitative and qualitative approaches, including questionnaires, interviews and case studies to establish in a more detailed way how the existing specialists in the field approach the concept of nanotechnology and what factors may affect their perception of it. Furthermore, the general background of quantum computing and nanotechnology research should also be considered. This field of study is not only cross-discipline but also cross-national, with many research contributions from institutions globally. The perceived and actual research context, funding options and emphases, and technology availability and use can vary significantly across countries and thus may affect the different professionals' views on and interactions with nanotechnology (Battistel et al., 2023).

Cross-sectional comparison across various countries and areas may help to elucidate how the variation of research framework and strategy influences quantum computing advancement. Such studies could also contribute to defining the most effective approaches and most successful cases of nanotechnology application in quantum computing in various contexts. Last but not least, the theoretical and practical implications of this study for education and training in quantum computing and nanotechnology are discussed. The fact that graduate students as well as early-career professionals have the same perception as senior researchers indicates that the current training programs effectively indoctrinate the subject. However, as quantum computing is still a growing field, there will be a need to make sure that the courses being offered will help equip the students to be able to contribute to the ever-growing field of quantum computing. It may involve increasing the practical practice of the use of nanotechnology tools and methods and offering the student a chance to participate in interdisciplinary research activities (Shaker, Al-Amiery, Isahak, & Al-Azzawi, 2023).

Nevertheless, as quantum computing is becoming more and more close to the market, there will be more opportunities for professionals who can translate academic knowledge to practical use. Quantum technologies, therefore, need not only the technical know-how but also the competence to grasp the economic, ethical, and societal consequences of quantum technology. They should also cover such broader concerns to equip the learners for future management of quantum computing technologies. In conclusion, the purpose of this study is to extend the current literature and gain an understanding of the views held by experts in the quantum computing and nanotechnology profession on the importance of nanotechnology in the advancement of quantum computing (Lougovski et al., 2023).

Through the analysis of the differences between the respondents' profiles, their levels of experience and knowledge about quantum bits, this study sheds light on the factors influencing such perception and gaps which should be addressed in future research. The conclusions of this work can be useful for the further discussion of the prospects for quantum computing and for the work on overcoming the challenges associated with creating useful quantum computing systems (Peters, 2023).

CONCLUSION:

Nanotechnology combined with quantum computing can be considered one of the most promising areas for the further development of computational power and technological evolution. The purpose of this research was to assess the understanding of the professionals on the importance of nanotechnology in quantum computing as well as the determinants of the understanding. Therefore, based on the analysis of the survey data: chi-square tests, ANOVA, T-tests, correlation analysis, and regression analysis, the study revealed the perceptions of the experts in the field concerning the role of nanotechnology, the challenges, and the prospects that may be expected.

Another common trend that emerged from this study is that all of the professionals from different disciplines and with different years of experience recognize the significance of nanotechnology in the improvement of quantum computing. The chi-square tests of independence showed that there were no significant differences in the perception based on the respondents' fields of expertise and their understanding of quantum bits which indicated the fact that the role of nanotechnology is recognized is not tied to the expertise of the respondents as well as the general understanding of quantum bits. This is supported by the ANOVA and T-test analysis which revealed that there were no differences in the perceptions among the different experience levels or career stages. These findings provide evidence of the fact that there is a general appreciation within the scientific community of the need for nanotechnology to address the technical impediments that limit quantum computing.

The correlation analysis that revealed that there is no significant difference in the perception of nanotechnology among the participants with different years of experience also supports the assertion that both the novices and the veterans in the field appreciate the importance of nanotechnology. This broad recognition could be due to a rich communication culture in the field that has passed the message that nanotechnology has to be included in quantum computing research and development. The absence of many differences also points to the appropriateness of the interdisciplinary approach to understanding the prospects and problems of quantum computing.

However, the regression analysis showed that years of experience and understanding of qubits account for a small amount of the variance in perceptions of the importance of nanotechnology. This implies that other factors are beyond the scope of this study which may have a higher influence on the perception of the professionals on the application of nanotechnology in quantum computing. Some of these factors may include; the research interest area, availability of state–of–the–art equipment, support for interdisciplinary innovations, or opportunity to work with international partners. Further research should be directed to these variables to have a better understanding of the factors that affect perception towards nanotechnology and how the perception can be used to promote the field.

The relevance of this study is premised on the fact that it helps to advance the conversation regarding the future of quantum computing as well as the imperative of nanotechnology in the said field. Thus, the findings of this study support the argument of the importance of nanotechnology, and, thus, strongly suggest further investment in nanotechnology R&D. The current study also underlines the significance of encouraging cross-disciplinary cooperation and monitoring the relevance of educational programmes to current and prospective practice. As quantum computing progresses in the future, the incorporation of nanotechnology will be crucial for the technological hurdles associated with the growth of quantum systems, the provision of efficient error correction, and the design of new quantum devices.

The study also has significant policy implications as well as for funding bodies and research institutes. The general agreement on the significance of nanotechnology indicates that enhancement of funding and support for its research should be sustained especially for the areas that enhance the development of quantum computing. This involves not only the creation of qubits and their management but also the creation of the entire quantum computing environment, for instance, cryogenic systems and nanostructures that can function effectively at sub-zero temperatures. Furthermore, the research indicates that backing for interdisciplinarity and global cooperation concerning research projects related to quantum computing technologies will be vital.

Thus, the present work offers useful information about the opinions of experts on the role of nanotechnology in quantum computing. The results imply that there is general agreement within the scientific community as to the significance of nanotechnology, irrespective of specialization, seniority or position. However, the study also underscores the need for further work to elucidate the precise factors that shape these attitudes and to discover the obstacles that must be surmounted for quantum computing to reach its potential. Thus, the following research questions can help to further the current work on building practical quantum computing systems that are robust and efficient. It can only be expected that the constant development and advancement of nanotechnology and its application to quantum computing will significantly contribute to the achievement of these objectives as well as the advancement of technology in the future.

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