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Research Article

Trends, Gaps, and Research Trajectories in Quantum Computing: A Comprehensive Systematic and Bibliometric Review

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ABSTRACT

This paper presents a comprehensive systematic and bibliometric review of the rapidly expanding literature on quantum computing. The study addresses six research questions concerning prominent themes, temporal evolution, types of key findings, frequently reported research gaps, higher-order gap typologies, and future research directions. Utilizing a researcher-curated database, the final corpus comprises 153 studies compiled from non-Scopus, Scopus and Web of Science. The results demonstrate that quantum hardware and architecture, algorithms, and theoretical foundations dominate the current literature. Furthermore, publication output has risen significantly between 2018 and 2025. Among the reported findings, algorithmic innovations, performance claims, and hardware advancements are the most common. Despite this progress, the field faces substantial barriers; technical, scalability, fault-tolerance, and methodological-standardization gaps are the most frequently reported. Based on these identified gaps, eight actionable future research directions emerge to guide the scientific community. Ultimately, this review concludes that quantum computing is actively transitioning from a purely physics-driven domain into a multidisciplinary, engineering- and application-oriented science. However, its continued advancement is presently constrained by a hardware-methodology-application triad, wherein reporting practices often outpace empirical verification and standardized benchmarking.

Keywords: *Gaps, Quantum computing, Research landscape, Systematic bibliometric review, Trajectories, Trends*

Introduction

Quantum computing represents a major technological frontier enabled by the principles of superposition, entanglement, and quantum interference, promising computational capabilities exponentially beyond classical systems for

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specific problem classes. Over the past decades, the field has evolved from early theoretical constructs (Deutsch, 1985; Feynman, 1982) to landmark demonstrations of search and factoring algorithms (Grover, 1996; Shor, 1994), culminating in recent demonstrations such as Google's 2019 quantum supremacy claim (Arute et al., 2019). However, the field currently remains in the Noisy Intermediate-Scale Quantum (NISQ) era, which is characterized by devices prone to errors and decoherence (Preskill, 2018). Consequently, there remains a substantial gap between current device capabilities and the fault-tolerant, large-scale quantum systems required for transformative real-world applications.

Existing reviews of quantum computing literature have tended to focus narrowly on distinct subfields, such as quantum algorithms (Montanaro, 2016), error correction (Devitt et al., 2013), or quantum machine learning (Biamonte et al., 2017). This narrow focus leaves a lack of an integrated, field-wide synthesis. Researchers, practitioners, and policymakers face considerable difficulty in developing a coherent understanding of the field's thematic structure, its trajectory over time, the nature of key scholarly contributions, and the persistent knowledge gaps that impede progress toward practical, large-scale quantum advantage. Synthesizing this understanding is essential, as the significance of quantum computing spans academic, strategic, industry, educational, and societal domains.

Statement of the Problem

To address this fragmented landscape, this study conducts a dual-method systematic and bibliometric review designed to illuminate the field's overarching dynamics. Specifically, this study is guided by six primary research questions:

1. What are the research themes in quantum computing based on the selected studies?
2. How have research themes and focus areas in quantum computing evolved over time?
3. What are the most common types of key findings reported in quantum computing studies?
4. What are the most frequently reported research gaps in quantum computing literature?
5. How can the identified research gaps be categorized into higher-order typologies?
6. What future research directions can be proposed based on the identified gaps and trends?

Literature Review

Theoretical Foundations

The intellectual foundations of quantum computing rest on crucial contributions to quantum mechanics and computational theory. Feynman (1982) and Deutsch (1985) laid the groundwork for simulating physics and establishing the universal quantum computer. Deutsch and Jozsa (1992) provided an early demonstration of quantum speedup, and Nielsen and Chuang (2010) subsequently synthesized the field's pedagogical and technical framework. Preskill (1998) extended this framework to quantum information theory, later conceptualizing the milestones of "quantum supremacy" and quantum advantage (Preskill, 2012). To understand the practical scope of these advantages, complexity-theoretic foundations have been vigorously explored (Aaronson, 2013; Bernstein & Vazirani, 1993; Watrous, 2009).

Quantum Algorithms

Algorithms represent a prolific subfield anchored by Shor (1994) and Grover (1996). More recently, variational and hybrid classical-quantum algorithms have been designed specifically to tolerate the moderate noise of NISQ-era devices (Cerezo et al., 2021; Farhi et al., 2014; Peruzzo et al., 2014). Additionally, quantum simulation algorithms have demonstrated potential for quantum chemistry and materials science (Babbush et al., 2018; Cade et al., 2020; Motta & Rice, 2022). The HHL algorithm introduced an exponential speedup for solving linear systems of equations (Harrow et al., 2009), though critical practical caveats persist (Aaronson, 2015). Demonstrating quantum advantage beyond highly structured, specific computational tasks remains a persistent open frontier (Bravyi et al., 2018; Montanaro, 2016).

Hardware and Implementations

The physical realization of quantum computers pursues multiple platforms. Superconducting qubit systems have achieved substantial scale and prominent milestones (Arute et al., 2019; IBM Quantum, 2022; Nakamura et al., 1999). Trapped-ion systems offer superior gate fidelities but face unique scalability challenges (Blatt & Wineland, 2008; Bruzewicz et al., 2019; Cirac & Zoller, 1995). Alternative architectures include photonic computing (Kok et al., 2007; Madsen et al., 2022), topological qubits (Freedman et al., 2003; Nayak et al., 2008), silicon spin qubits (Loss & DiVincenzo, 1998; Philips et al., 2022), and nitrogen-vacancy centers (Doherty et al., 2013). Across all platforms, managing decoherence and maintaining qubit states remain fundamental engineering challenges (DiVincenzo, 2000; Krantz et al., 2019; Ladd et al., 2010).

Error Correction and Fault Tolerance

Because physical qubits are prone to error, quantum error correction is theoretically indispensable for scaling computation (Gottesman, 1997; Shor, 1995; Steane, 1996). Foundational work established that fault-tolerant computation is possible if error rates fall below a critical threshold (Aharonov & Ben-Or, 1997; Knill et al., 1998; Preskill, 1998). The surface code has emerged as a leading practical candidate (Fowler et al., 2012; Kitaev, 2003), and recent experiments have validated its application at a small scale (Acharya et al., 2023). However, the massive ratio of physical to logical qubits required constitutes a critical scalability bottleneck (Campbell et al., 2017; Devitt et al., 2013).

Cryptography and Post-Quantum Security

Quantum cryptography encompasses both the achievement of provably secure communications and the threat quantum computing poses to classical systems. Quantum key distribution guarantees security via quantum mechanical principles (Bennett & Brassard, 1984;

Ekert, 1991), with notable achievements in long-distance and satellite-based distribution (Boaron et al., 2018; Liao et al., 2017; Yin et al., 2017). Conversely, quantum capabilities directly threaten current internet security infrastructure (Mosca, 2018), prompting robust initiatives for post-quantum cryptographic standardization (Bernstein & Lange, 2017; NIST, 2022).

Quantum Machine Learning

Quantum machine learning (QML) has emerged as a distinct subfield aimed at uncovering quantum speedups for data processing (Biamonte et al., 2017; Lloyd et al., 2013; Rebentrost et al., 2014). However, reassessments have demonstrated that many proposed speedups are classically dequantizable (Aaronson, 2015; Tang, 2019). Consequently, variational approaches and quantum neural networks have been proposed as hardware-compatible alternatives (Abbas et al., 2021; Havlicek et al., 2019). Despite these advancements, robust quantum advantage for practical machine learning tasks remains a highly contested issue (Cerezo et al., 2022).

Quantum Networking and Communication

The vision for a quantum internet involves connecting quantum devices to enable distributed computation and secure global communication (Kimble, 2008; Wehner et al., 2018). This relies heavily on advancements in quantum teleportation (Bennett et al., 1993; Bouwmeester et al., 1997) and quantum repeaters (Briegel et al., 1998; Sangouard et al., 2011). Experimental progress has increasingly demonstrated metropolitan and multinode quantum network capabilities (Pompili et al., 2021; Stephenson et al., 2020).

Bibliometric Studies

Previous bibliometric analyses of quantum computing have documented growth patterns (Seskir et al., 2022), identified publication trends and collaborative networks (Bernal et al., 2023), and mapped narrow subfields such as quantum sensing (Torres-Alba et al., 2024).

However, a critical gap remains: no prior study combines full-breadth bibliometric mapping with systematic qualitative synthesis across all major quantum computing domains.

Conceptual Framework

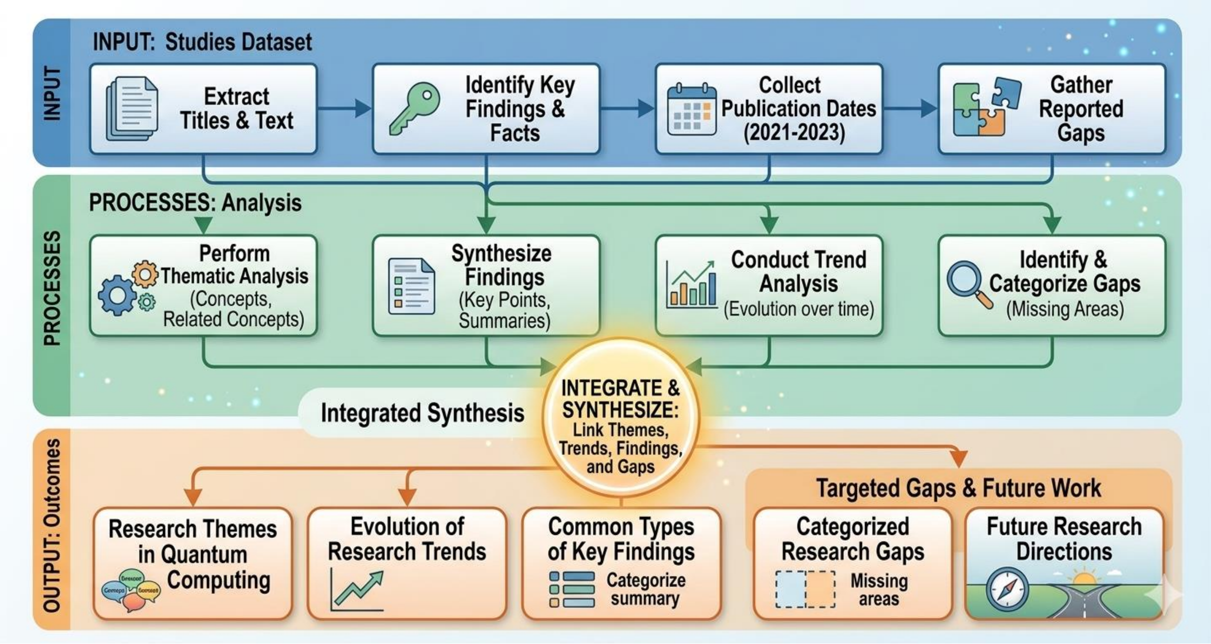

Figure 1. Conceptual Framework

Methodology

This study used a mixed-methods design combining a systematic literature review with bibliometric analysis. The systematic component followed the PRISMA 2020 guidelines for identification, screening, eligibility, and inclusion. The corpus consisted of 153 studies stored in a researcher-curated database (Allstudies.xlsx) comprising eleven fields: Title, Journal Name, Journal Type, Indexing Database, DOI, Keywords, Key Findings, Research Gaps, Publication Date, Author Details, and Access Link. Publications in the corpus spanned the years 2000 to 2026, with 142 studies (92.8%) originating from 2021 onward. Beyond Scopus and Web of Science, the “non-Scopus” portion of the corpus was drawn from the arXiv preprint repository (quant-ph listing), IEEE Xplore, the ACM Digital Library, SpringerLink, Nature Portfolio journals, and the APS Physical Review family, together with records surfaced through Google Scholar and Dimensions used as secondary indexes for cross-verification of metadata and DOIs.

Inclusion criteria required that studies explicitly addressed quantum computing; reported identifiable key findings and at least one research gap; were published in peer-reviewed journals, academic/scientific outlets, review venues, or recognized preprint repositories such as arXiv; and were retrievable through a verifiable DOI or permanent URL. Exclusion criteria eliminated studies with inaccessible full text, those not directly about quantum computing, or those missing key analytic fields.

A three-layer coding framework was utilized. First, the title, keywords, and findings text for each study were concatenated. Second, a deductive codebook was generated from prior reviews. Third, inductive refinement incorporated emergent categories. Multiple non-exclusive theme tags were permitted per study. Parallel coding was applied to eight key-finding types and 12 specific gap categories, which were then aggregated into seven higher-order typologies. This framework was pilot-tested on 20 randomly selected studies to ensure reliability. During this pilot, two coders independently applied the codebook to the 20 studies. Inter-rater reliability was acceptable, with a mean Cohen’s $\kappa = 0.81$ across the theme, key-finding, and gap dimensions (percent agreement = 91%). Coding discrepancies were resolved through discussion, and the codebook was refined accordingly before it was applied to the full corpus.

All statistical treatment was conducted in Python 3 (*pandas 2.x; SciPy 1.x*). Analytical procedures included descriptive statistics, frequency analysis, chi-square goodness-of-fit tests, linear regression, the Mann–Kendall trend test, Compound Annual Growth Rate (CAGR) calculation from 2021 to 2025, theme-by-period cross-tabulation, and narrative synthesis.

Statistical significance was set at α = .05. Because thematic and gap coding was nonexclusive, percentages may exceed 100%. The year 2026 was treated as a partial year and subsequently excluded from longitudinal trend tests.

Results

The systematic screening process yielded 153 studies. Table 1 presents the descriptive profile of the final corpus. The data reveal that the corpus is highly recent and consists predominantly of peer-reviewed journal literature.

Table 1. Descriptive Profile of the Systematic Review Corpus (N = 153)

Variable	**n**	**%**
Total included studies	153	100.0
Studies with parseable publication year	151	98.7
Year range	2018–2026	—
Mean publication year (2018–2026)	2023.43	—
Median publication year	2024	—
Modal publication year	2024	—
Standard deviation of publication year	1.78	—
Journal type: Peer-Reviewed Journal	99	64.7
Journal type: Review Article	21	13.7
Journal type: Academic/Scientific Journal	12	7.8
Journal type: Other	12	7.8
Journal type: Preprint Repository	6	3.9
Journal type: Unspecified	2	1.3
Journal type: Conference Proceedings	1	0.7

Note. Descriptive values were computed for N = 153 included studies. Percentages for journal type are computed over the full corpus.

To address RQ1, Table 2 maps the distribution of research themes. The analysis identifies three macro-clusters: technology-building, theory-and-physics, and applied/integrative themes, with hardware and algorithms emerging as the most dominant.

Table 2. Distribution of Research Themes Across the Reviewed Studies (RQ1)

Research theme	**n**	**%**
Quantum Hardware & Architecture	89	58.2
Quantum Algorithms & Computational Methods	58	37.9
Physics & Theoretical Foundations	48	31.4
Optimization & Operations Research	45	29.4
Quantum Error Correction & Fault Tolerance	44	28.8
AI & Machine Learning Integration	44	28.8
Quantum Communication & Networking	41	26.8
Quantum Cryptography & Security	37	24.2
Reviews & Bibliometric Studies	31	20.3
Healthcare & Biomedical Applications	31	20.3
Quantum Chemistry & Materials Science	29	19

Research theme	**n**	**%**
Quantum Software & Programming	23	15
Energy & Power Systems	22	14.4
Finance & Business Applications	18	11.8
Education, Workforce & Policy	12	7.8

Note. N = 153. Themes are not mutually exclusive; studies could be tagged with multiple themes, so percentages do not sum to 100%. Themes were derived via combined deductive–inductive coding of titles, keywords, and key findings.

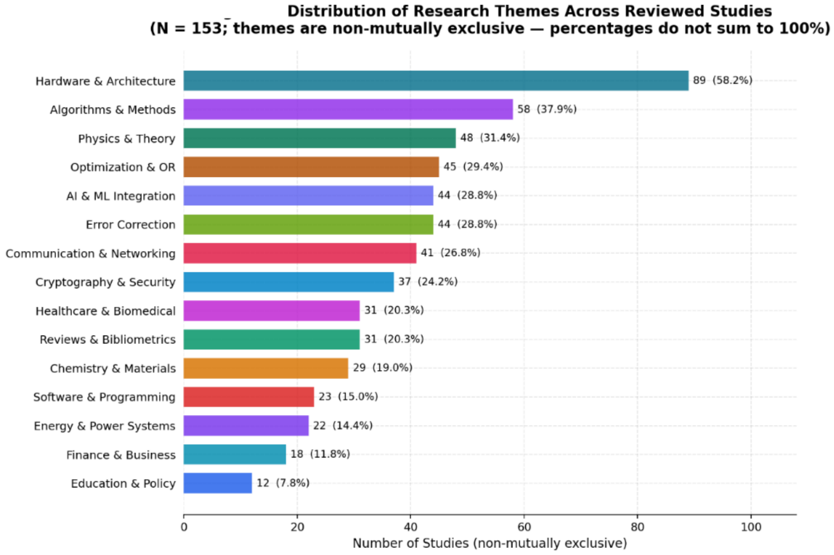

Figure 2. Distribution of Themes

Table 3 tracks the temporal evolution of the field (RQ2), revealing a strong upward trend in publication output. A statistically significant monotonic increase was established, and a chi-square test rejected the null hypothesis of a uniform yearly distribution (χZ = 80.635, df = 7, p = 0). The 2026 count is reported in Table 3 for descriptive purposes only—to illustrate ongoing research activity at the time of data collection—and was not entered into the longitudinal trend tests, since 2026 represents an incomplete year of publication data and its inclusion would understate the true annual output and bias the growth trajectory.

Table 3. Annual Publication Output of Quantum Computing Studies (RQ2)

Year	**n**	**%**
2018	2	1.3
2019	5	3.3
2020	1	0.7
2021	13	8.5
2022	20	13.1
2023	26	17
2024	36	23.5
2025	34	22.2
2026	13	8.5

Note. N = 151 (studies with a parse able publication year / reporting at least one gap); two records lacked a usable year and were excluded. Linear trend (2018–2025): slope = 5.49 studies/year, R^2 *= 0.916, p = 0.0002. Mann–Kendall trend test: Z = 2.598, p = 0.0094. Compound annual growth rate (2021–2025) = 27.17%. The 2026 count reflects a partial year and was excluded from trend tests.*

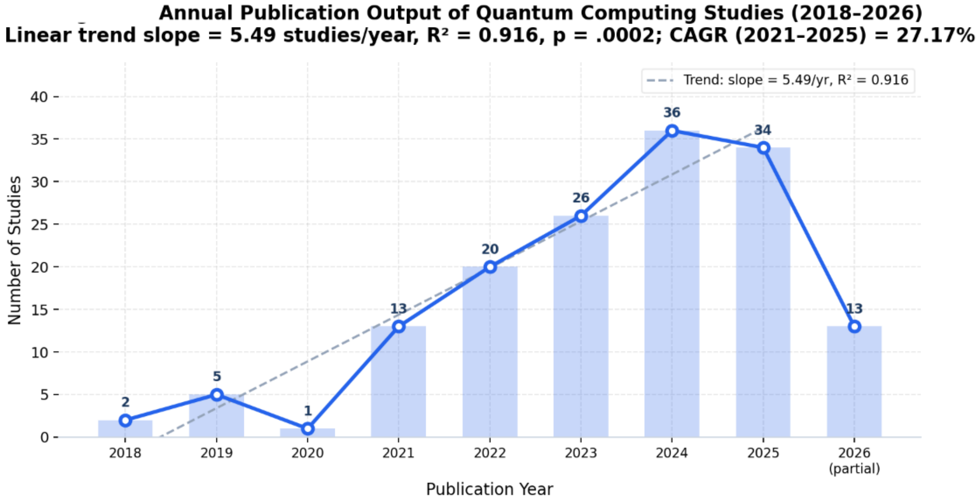

Figure 3. Annual Publication Output

Table 4 provides an expanded view of thematic evolution (RQ2), demonstrating a shift from NISQ-era hardware stabilization in the early period toward diversified applications and hybrid AI-enabled workflows in more recent years.

Table 4. Research Themes by Time Period, 2018–2026 (RQ2)

Research theme	**2018–2020 (Early)**	**2021–2022 (Growth)**	**2023–2024 (Maturation)**	**2025–2026 (Current)**	**Total**
Quantum Hardware & Architecture	8	20	40	20	88
Quantum Algorithms & Computational Methods	5	11	25	17	58
Physics & Theoretical Foundations	4	9	23	12	48
Optimization & Operations Research	2	13	15	15	45
Quantum Error Correction & Fault Tolerance	5	9	13	17	44
AI & Machine Learning Integration	3	4	19	18	44
Quantum Communication & Networking	2	4	23	12	41
Quantum Cryptography & Security	2	4	18	13	37
Healthcare & Biomedical Applications	2	3	15	11	31
Reviews & Bibliometric Studies	1	3	13	13	30
Quantum Chemistry & Materials Science	0	8	13	8	29
Energy & Power Systems	0	5	10	7	22
Quantum Software & Programming	3	4	11	4	22

Research theme	2018–2020 (Early)	2021–2022 (Growth)	2023–2024 (Maturation)	2025–2026 (Current)	Total
Finance & Business Applications	0	4	4	10	18
Education, Workforce & Policy	0	2	2	8	12

Note. N = 152 studies with parse able publication year; one record (year = 2000) was excluded. Confirm 151 vs 152 is intentional and explained. Cell values are theme-assignment counts; themes are non-mutually exclusive. Periods: Early = 2018–2020; Growth = 2021–2022; Maturation = 2023–2024; Current = 2025–2026 (partial).

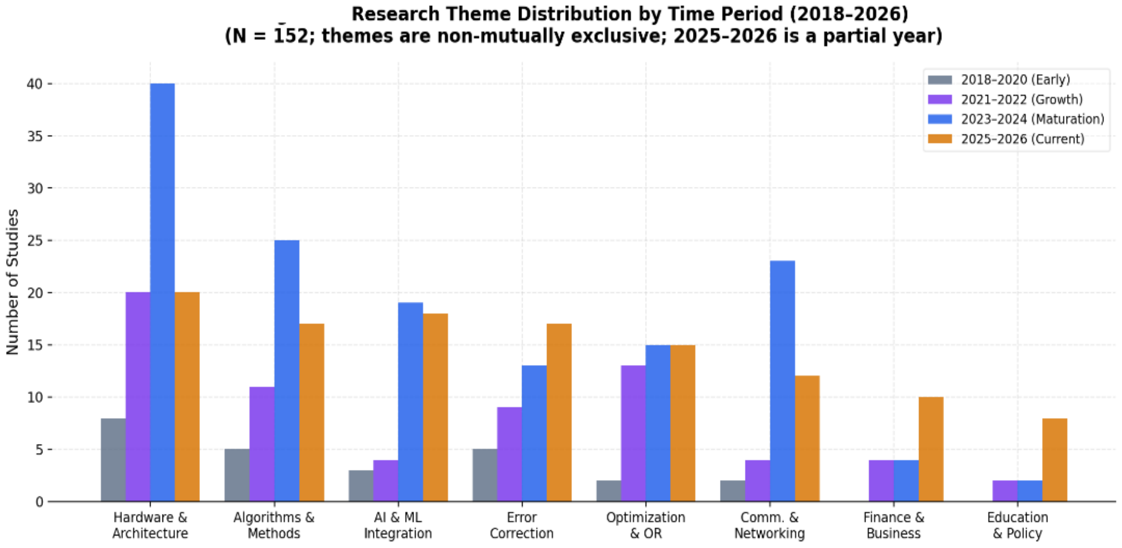

Figure 4. Research Theme Distribution

Regarding the types of key findings (RQ3), Table 5 illustrates that algorithmic and methodological innovations, performance claims, and hardware advances dominate the reported outcomes across the literature.

Table 5. Frequency and Percentage of Key-Finding Types Reported in Reviewed Studies (RQ3)

Type of key finding	n	%
Algorithmic / Methodological Innovations	97	63.4
Performance / Quantum Advantage	78	51
Hardware Advancements	77	50.3
Application-Specific Results	68	44.4
Experimental / Empirical Demonstrations	65	42.5
Theoretical / Conceptual Contributions	61	39.9
Hybrid / Integrative Approaches	48	31.4
Review / Landscape Mapping Findings	24	15.7

Note. N = 153. Finding types are non-mutually exclusive; each study may report findings of multiple types. Percentages are computed over the full corpus.

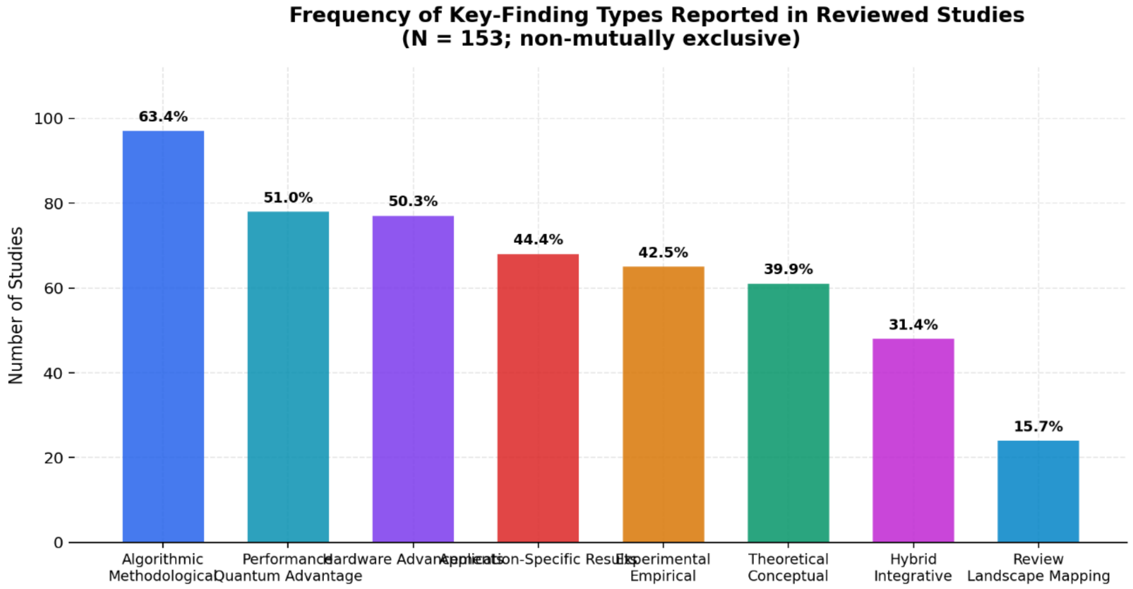

Figure 5. Reported Frequency of Key-Finding Types

Table 6 catalogs the frequently reported research gaps (RQ4), identifying technical and hardware limitations, as well as scalability issues, as the most pervasive barriers within the current paradigm.

Table 6. Frequency and Percentage of Reported Research Gaps Across Studies (RQ4)

Research gap category	**n**	**%**
Technical / Hardware Limitations	105	69.5
Scalability Issues	98	64.9
Algorithmic / Methodological Gaps	59	39.1
Error Correction & Fault Tolerance Gaps	54	35.8
Software, Tools & Standardization Gaps	40	26.5
Theoretical / Conceptual Gaps	39	25.8
Experimental / Empirical Gaps	37	24.5
Cost / Infrastructure / Accessibility Gaps	34	22.5
Interdisciplinary / Integration Gaps	33	21.9
Application-Specific / Domain Gaps	17	11.3
Ethical, Social & Regulatory Gaps	17	11.3
Workforce, Education & Skills Gaps	14	9.3

Note. N = 151 (studies with a parseable publication year / reporting at least one gap); two records lacked a usable year and were excluded. Gap categories are non-mutually exclusive; each study may report multiple gaps. Percentages are computed over the n = 151 studies that reported a gap.

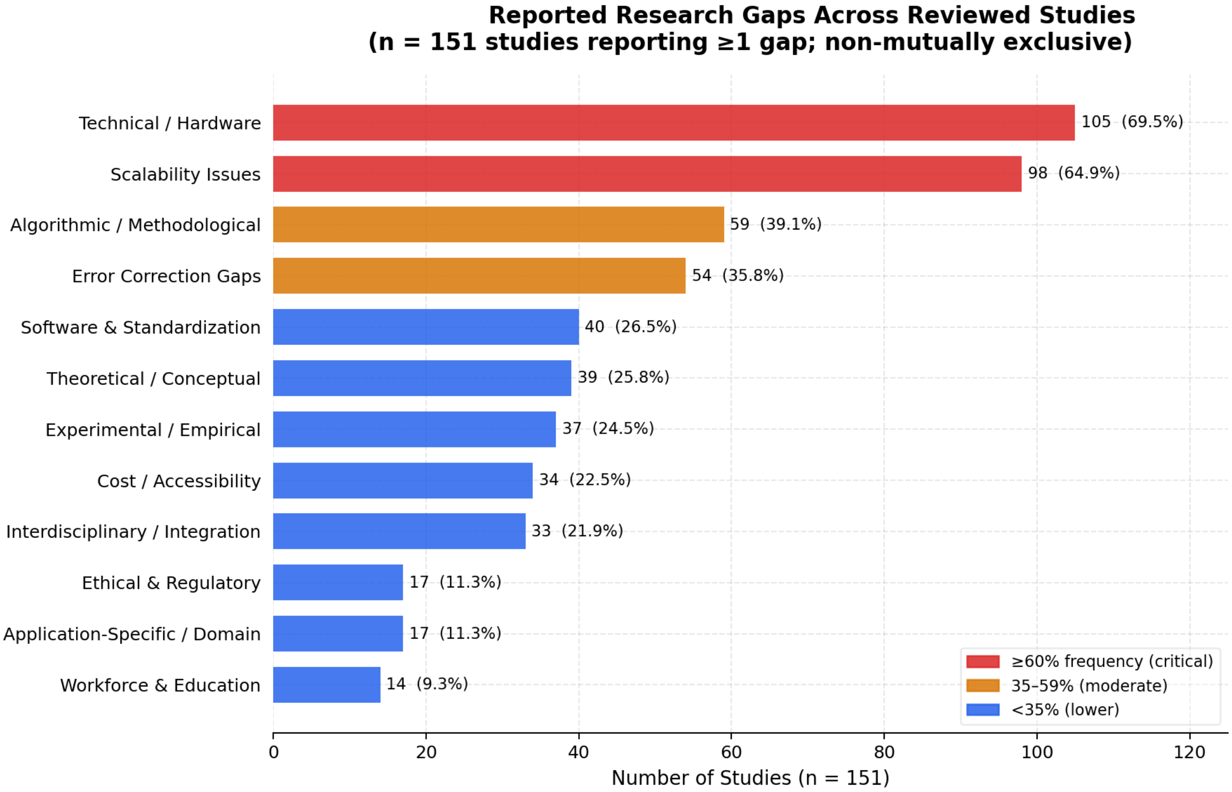

Figure 6. Reported Research Gaps Across Reviewed Studies

To systematically categorize these gaps (RQ5), Table 7 collapses them into seven higher-order typologies. The distribution confirms that the field remains heavily encumbered by technical and methodological or standardization concerns.

Table 7. Broad Typological Classification of Research Gaps in Quantum Computing (RQ5)

Gap typology	**n**	**%**
Technical	120	79.5
Methodological / Standardization	82	54.3
Integrative / Interdisciplinary	46	30.5
Infrastructural / Human Capital	43	28.5
Theoretical	39	25.8
Experimental	37	24.5
Ethical / Social / Regulatory	17	11.3

Note. N = 151 (studies with a parse able publication year / reporting at least one gap); two records lacked a usable year and were excluded. Typologies aggregate the specific gap categories in Table 6 into seven higher-order classes. A chi-square goodness-of-fit test for equal distribution across the seven typologies yielded $\chi^2 = 131.302$, df = 6, p < .001, indicating that gaps are not evenly distributed and are concentrated in the Technical and Methodological/Standardization classes.

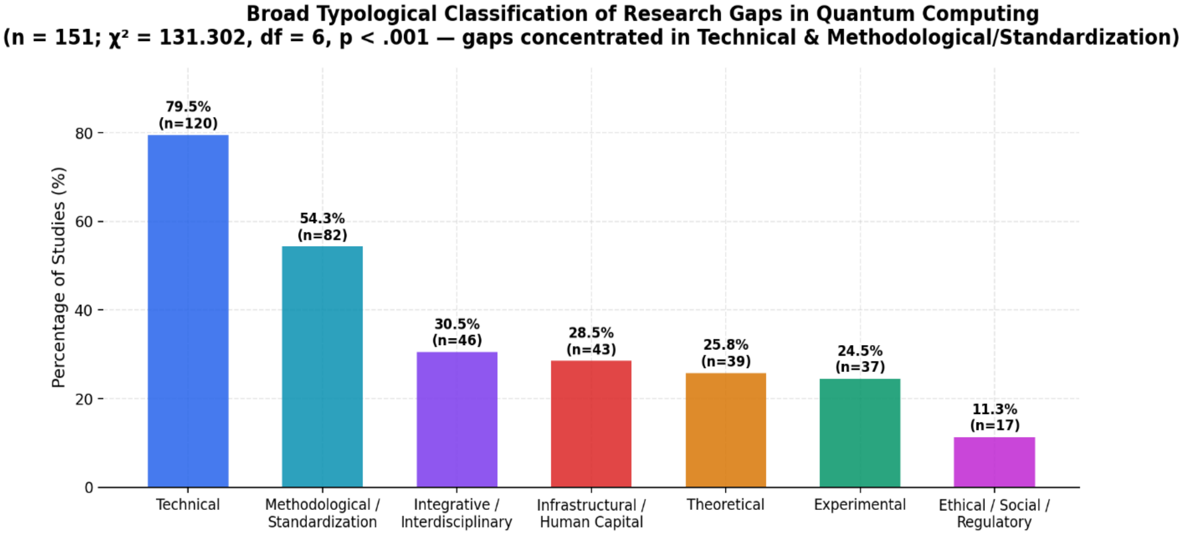

Figure 7. Broad Typological Classification

To link the higher-order typologies in Table 7 back to the specific categories in Table 6, the two dominant typologies are driven by the following leading gap categories:

Technical typology (n = 120; 79.5%): driven chiefly by Technical / Hardware Limitations (n = 105; 69.5%) and Scalability Issues (n = 98; 64.9%).

Methodological / Standardization typology (n = 82; 54.3%): driven chiefly by Algorithmic / Methodological Gaps (n = 59; 39.1%) and Software, Tools & Standardization Gaps (n = 40; 26.5%).

Based on the identified themes and gaps, Table 8 synthesizes an evidence-based future research agenda (RQ6), prioritizing areas such as scalable fault-tolerant architectures and robust software engineering practices.

Table 8. Proposed Future Research Directions Derived from Trends and Gaps (RQ6)

Future research direction	Rationale
Scalable Fault-Tolerant Architectures	Develop qubit designs and error-correcting codes (e.g., surface, LDPC, color codes) that achieve logical-qubit stability beyond the NISQ era.
Standardized Benchmarking and Software Stacks	Establish shared benchmarks (QBench-type), reference architectures, and reproducibility protocols for quantum-software engineering.
Hybrid Quantum–Classical Workflows	Mature variational, hybrid, and AI-assisted algorithms (VQE, QAOA, QML) that can be deployed on near-term noisy hardware.
Application-Driven Empirical Studies	Move validated use-cases in healthcare, chemistry, finance, and optimization from preclinical/laboratory demonstrations to real-world trials.
Interdisciplinary Integration with AI, IoT, and HPC	Create cross-domain pipelines combining quantum computing with AI, blockchain, IoT, and distributed/cloud computing.
Workforce and Curriculum Development	Design quantum-literate curricula and upskill programs to address the projected quantum-talent shortage.
Ethical, Social, and Regulatory Frameworks	Develop governance models for quantum cryptography, data privacy, equitable access, and dual-use risks.

Future research direction	**Rationale**
Quantum Cloud and Distributed QPUs	Advance distributed quantum computing, networked QPUs, and cloud access as scalability bridges toward utility-scale systems.

Note. Directions were derived deductively from the dominant themes (Tables 2 and 4) and gap profile (Tables 6 and 7). Each direction targets a gap cluster with the highest reported frequency or fastest thematic growth.

Several methodological caveats regarding the statistical treatment should be noted. Because codes are nonexclusive, percentages across categories often exceed 100%. Consequently, chi-square tests were utilized strictly on aggregate distributions where appropriate. Furthermore, because 2026 constitutes a partial year of data collection, it was excluded from trend tests to avoid artificial bias in the growth trajectory.

Discussion

The findings of this comprehensive review indicate that while the quantum computing field is broad, it remains fundamentally technology-anchored. The robust prominence of hardware, algorithm, and theoretical themes is symptomatic of the ongoing physical limitations inherent to the NISQ era (Preskill, 2018). However, the observed temporal evolution—marked by a shift away from exclusive NISQ-era hardware stabilization toward diversified applications and hybrid AI-enabled workflows—suggests a critical transition. The field is maturing from a strictly physics-driven discipline toward an interdisciplinary, engineering- and application-oriented science.

A primary interpretive finding from this corpus is the emergence of a "hardware–methodology–application triad." First, the technical core—including hardware constraints, decoherence (DiVincenzo, 2000), and fault-tolerance overhead (Campbell et al., 2017)—both drives and profoundly constrains progress. Second, there is a stark discrepancy between the high prevalence of algorithmic and performance claims and the substantial volume of methodological and standardization gaps. This dynamic suggests that current reporting practices may be actively outpacing verification practices, as standardized benchmarking lags behind theoretical claims of quantum advantage. Third, applied themes are expanding at a rate that exceeds their empirical maturity, indicating that applications are being conceptually hypothesized faster than real-world systems can validate them. The relative weight within this triad is likely to shift as the field moves beyond the NISQ era. As fault-tolerant prototypes mature over the next five years, the primary bottleneck is expected to migrate away from raw hardware and toward the methodological element—specifically the absence of standardized benchmarking, reproducibility protocols, and verification practices needed to substantiate quantum-advantage claims. In other words, even as physical qubit counts and error rates improve, progress will be gated less by device availability than by the field's capacity to rigorously and comparably evaluate what those devices actually achieve, with application-level validation emerging as the subsequent constraint once methodological standardization matures.

Addressing these structural constraints yields implications across multiple spheres. Academically and practically, establishing shared benchmarking frameworks is essential to rigorously verify performance claims. The need for standardized benchmarking is itself a symptom of the academic–industrial divide: academic work tends to optimize for novel algorithmic and performance claims, whereas industrial deployment requires reproducible, comparable, and audited metrics. Bridging this divide will likely depend on neutral standards bodies and industry-led consortia—for example, the role NIST has played in post-quantum cryptographic standardization (NIST, 2022), and analogous community efforts toward shared performance metrics and reference architectures—to define common benchmarks that both communities can adopt, thereby aligning reporting practices with empirical verification. Strategically and industrially, investments in quantum cloud infrastructure, software engineering, and interdisciplinary integration are imperative to bridge the gap toward utility-scale applications. Additionally, as the threat model of cryptographically relevant quantum systems matures (Mosca, 2018), responsible governance and proactive post-quantum regulatory frameworks are increasingly necessary. Ultimately, alleviating these pressures requires cohesive workforce development programs designed to address both infrastructural accessibility and human-capital shortages.

Conclusion

This systematic and bibliometric review demonstrates that quantum computing is experiencing significant, statistically robust growth, characterized by rapidly diversifying research themes. Although the literature is swiftly expanding into applied domains such as healthcare, artificial intelligence, and operations research, the most frequently reported knowledge gaps remain intensely concentrated in technical hardware limitations and methodological standardization. By synthesizing these gaps, this study presents an evidence-based forward agenda prioritizing scalable fault-tolerant architectures, standardized software stacks, and cross-domain integration. The transition from theoretical promise to practical, large-scale utility depends not only on continued advances in physical qubits but equally on rigorous standardization, reproducibility, interdisciplinary integration, institutional capacity, and responsible governance

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