UNDERSTANDING SOFTWARE DEVELOPER ADAPTATION TO QUANTUM COMPUTING ARCHITECTURAL CONCEPTS

Sameena Tabbsum[*1], Syed Zaffar Iqbal[2], Palwasha Khalid[3]

[*1]MS Scholar, Department of Computer Science, Alhamd Islamic University, Quetta-Pakistan.
[2]Department of Computer Science, Alhamd Islamic University, Quetta-Pakistan.
[3]Program Coordinator, Department of Computer Science, Alhamd Islamic University, Quetta-Pakistan.

Corresponding Author: *
Sameena Tabbsum

Abstract

The rapid advancement of quantum computing presents significant challenges and opportunities for software developers accustomed to classical computing architectures. This study aims to explore how software developers understand, interpret and adapt to the emerging architectural concepts of quantum computing, focusing on their learning processes, conceptual transitions and professional adaptation strategies. A qualitative research design was employed, utilizing semi-structured interviews with twelve software developers from diverse professional backgrounds. Thematic analysis was conducted to identify patterns and themes related to developers' perceptions, challenges, and adaptation pathways concerning quantum computing concepts. Findings reveal a spectrum of adaptation experiences, highlighting three dominant themes: cognitive shift from deterministic to probabilistic thinking, perceived barriers including steep learning curves and lack of practical tools and motivational factors driven by industry relevance and future career prospects. Developers emphasized the critical role of targeted educational resources, community support and incremental exposure to quantum concepts in facilitating adaptation. The study concludes that software developers experience a transformative yet challenging journey when adapting to quantum computing architectures. Tailored learning frameworks, practical experimentation opportunities and industry-academia collaborations can enhance the adaptive capacity of developers, enabling a smoother transition to quantum paradigms.

INTRODUCTION

Background and Motivation

The emergence of quantum computing represents a transformative paradigm shift in computational theory and practice, with the potential to solve complex problems intractable for classical computers [1]. Quantum computing harnesses principles such as superposition, entanglement, and quantum interference to process information in fundamentally different ways than traditional von Neumann architectures [2]. As organizations and industries begin to explore quantum applications in cryptography, optimization, and machine learning, there is an increasing need for software developers to acquire competencies in quantum computing concepts and architectures [3].

Despite the increasing research focus on quantum algorithms and hardware development, relatively little attention has been given to the human dimension of this technological shift, particularly the adaptation journey of software developers. Existing literature predominantly addresses the mathematical foundations and engineering challenges of quantum

computing [4], with limited qualitative insight into how software practitioners interpret, internalize, and adapt to these new architectural concepts. This knowledge gap is particularly critical as developers serve as the key enablers of technological adoption in organizational settings [5].

The motivation for this study stems from the need to understand the practical challenges, cognitive transitions, and motivational factors that influence software developers' engagement with quantum computing. Understanding these factors is essential for designing effective training programs, educational curricula, and organizational strategies to foster a smoother transition into the quantum era. By focusing on the lived experiences of developers, this study aims to contribute to the growing discourse on human adaptation in emerging technologies [6].

Problem Statement

While technological advancements in quantum computing are progressing rapidly, the pace of software developer adaptation remains ambiguous and underexplored. Software developers, who are traditionally trained in deterministic and classical computing paradigms, face substantial cognitive and practical challenges when transitioning to quantum-based architectural concepts [7]. Preliminary observations indicate that a lack of accessible educational resources, steep learning curves, and unfamiliar abstract quantum mechanics principles pose significant barriers to effective adaptation [8].

This misalignment between technological evolution and human adaptation has implications for the successful integration of quantum solutions into mainstream software development practices. Without a deeper understanding of how developers perceive and navigate these challenges, there is a risk of delayed adoption, skills mismatches, and inefficient knowledge transfer in the technology workforce. Current literature offers minimal qualitative insight into these adaptation processes, underscoring the need for a focused investigation [9].

Purpose of the Study

The primary purpose of this qualitative study is to explore and understand the adaptation processes of software developers as they engage with quantum computing architectural concepts. By capturing

developers' experiences, perceptions, and learning pathways, the study aims to illuminate the cognitive, educational, and professional factors that facilitate or hinder this transition. Through semi-structured interviews and thematic analysis, the research seeks to offer grounded insights into the real-world adaptation journey of software developers facing the quantum paradigm shift.

This study intends to bridge the gap between technological innovation and human capacity building by providing empirical data on developers' challenges and adaptation strategies. The insights generated are expected to inform industry stakeholders, academic institutions, and policymakers in designing targeted interventions to enhance quantum computing literacy among the software development community.

Research Objectives

The study is guided by the following specific research objectives:

- To explore software developers' perceptions and understanding of quantum computing architectural concepts.
- To identify key challenges faced by software developers during the adaptation to quantum computing paradigms.
- To examine motivational and contextual factors influencing developers' engagement with quantum computing.
- To investigate the role of educational resources, peer networks, and organizational support in facilitating adaptation.
- To develop practical recommendations for improving software developer readiness for quantum computing transitions.

Significance of the Study

This study holds significance for multiple stakeholders within the technology ecosystem. For academia, it provides qualitative insights that can guide the development of more effective and accessible quantum computing educational materials tailored to software developers [10]. For industry, understanding adaptation processes can aid in crafting corporate training programs and professional development initiatives that address real-world learning barriers [11]. Additionally,

policymakers and curriculum designers can leverage the findings to ensure that national and organizational strategies for quantum computing adoption incorporate human-centered considerations.

By contributing to the limited body of qualitative research in this emerging field, the study fills an important knowledge gap and promotes a more balanced approach to quantum computing advancement—one that accounts for both technological progress and human adaptability.

Literature Review
Review of Relevant Theories

The process by which individuals adapt to disruptive technologies has been studied through various theoretical lenses. The Technology Acceptance Model (TAM) posits that perceived usefulness and perceived ease of use are fundamental in determining technology adoption [12]. However, TAM's quantitative focus often overlooks deeper cognitive and emotional factors influencing individual adaptation, which are critical when the technology, like quantum computing, involves complex abstract concepts [13]. Another useful perspective is Rogers' Diffusion of Innovations Theory, which identifies five categories of adopters and highlights how complexity acts as a barrier to adoption [14]. While these models provide foundational insights, their applicability to quantum computing adaptation—especially among software developers—remains underexplored in qualitative contexts.

Additionally, Cognitive Load Theory (CLT) offers explanations on how information processing capabilities are challenged when learners are introduced to highly complex subjects [15]. This theory is particularly relevant because quantum computing requires software developers to shift from deterministic to probabilistic reasoning, creating cognitive barriers that traditional educational paradigms do not adequately address. Despite these theoretical contributions, the literature lacks qualitative investigations into how these models manifest in the specific context of quantum computing adaptation among software practitioners.

Existing Studies in Computer Science

Quantum computing research has predominantly focused on hardware advancements [16], quantum algorithms [17], and mathematical models [18], with relatively limited attention to the human factors associated with its adoption. Some recent works have begun to explore the educational aspects, such as Gabor et al. [10], who examined pedagogical approaches for introducing quantum computing to computer science students. Their findings suggest that contextually relevant examples and gradual exposure reduce cognitive overload, but their study was quantitative in nature and limited to academic settings.

In the software engineering domain, Campagne and Delfosse [7] discuss the structural and conceptual challenges software engineers face when approaching quantum architectures, emphasizing the gap between classical design methodologies and quantum paradigms. Similarly, Duncan and Chua [11] highlight industry concerns regarding the readiness of the software development workforce to transition to quantum computing, citing a lack of training resources and organizational preparedness.

Studies like Wang and Wang [6] have reviewed technology adaptation processes in software engineering but do not specifically address quantum computing or use qualitative methodologies to understand developer experiences. This signifies a significant gap in the literature where the focus remains primarily on skills requirements rather than adaptation processes.

Identification of Gaps

Three critical gaps emerge from the existing body of literature. First, there is insufficient qualitative research exploring how practicing software developers conceptualize and internalize quantum computing architectures beyond academic environments. Second, limited focus exists on adaptation journeys, including motivational drivers and cognitive barriers, with most studies opting for quantitative surveys over qualitative narratives. Third, a practical understanding of adaptation enablers—such as specific educational tools, workplace strategies, and collaborative environments—remains fragmented and underdeveloped in current research.

These gaps suggest that while the technological aspects of quantum computing are well-researched, the human element—particularly how developers adapt cognitively, professionally, and socially—requires dedicated qualitative inquiry.

Conceptual Framework

Grounded in the review of relevant theories and empirical studies, this study adopts a conceptual framework focusing on three primary dimensions of adaptation:

• Cognitive Adaptation, referring to the mental transition from classical to quantum computing paradigms, influenced by perceived complexity and learning resources.

• Motivational Adaptation, involving intrinsic and extrinsic factors that encourage or discourage developers to engage with quantum computing.

• Contextual Adaptation, examining how workplace culture, educational resources, and professional networks facilitate or hinder adaptation processes.

This framework is guided by Cognitive Load Theory, elements of Technology Acceptance Model, and the Diffusion of Innovations Theory, but seeks to enrich these models through grounded qualitative data derived from software developers lived experiences.

By employing this framework, the study aims to generate in-depth, context-sensitive insights into the adaptation processes, addressing a notable gap in the current literature on quantum computing's human and professional dimensions.
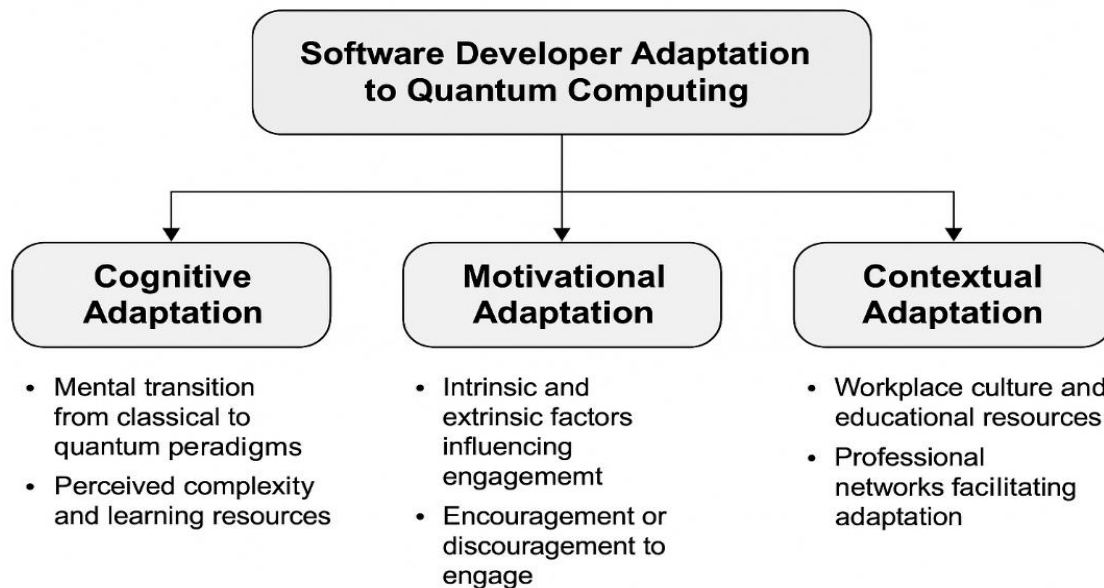

Fig. 1 Conceptual Framework for understanding software developer adaptation to quantum computing architectural concepts

Figure 1 presents the conceptual framework for understanding software developer adaptation to quantum computing architectural concepts. The framework is structured around three key dimensions: Cognitive Adaptation, Motivational Adaptation, and Contextual Adaptation. Cognitive Adaptation focuses on the mental transition from classical to quantum paradigms, emphasizing perceived complexity and the role of learning resources. Motivational Adaptation highlights intrinsic and extrinsic factors that either encourage or discourage developers' engagement with quantum computing. Contextual Adaptation addresses the influence of workplace culture, educational resources, and professional networks in facilitating the adaptation process. This multi-dimensional approach aims to provide a comprehensive understanding of how software developers internalize and adapt to the emerging quantum computing landscape.

Research Methodology

Research Design

This study adopts a **qualitative exploratory research design** to investigate the adaptation processes of software developers to quantum computing architectural concepts. Qualitative research is particularly suitable for this study because it facilitates in-depth exploration of subjective experiences, perceptions, and behaviors that quantitative methods might overlook [19]. By employing an inductive approach, the research aims to capture the complexity of human adaptation in response to the abstract and technical nature of quantum computing. This design aligns with existing qualitative traditions in technology adoption studies, where understanding personal narratives is central to theory development [20].

Data Collection Methods

To ensure a rich and diverse data set, the study utilizes triangulation of data collection methods, including semi-structured interviews, focus group discussions, and document analysis.

1) Semi-Structured Interviews:

Primary data collection involves in-depth, semi-structured interviews with 12-15 software developers from varying professional backgrounds and levels of exposure to quantum computing. This method allows flexibility in probing participants' unique adaptation journeys while ensuring alignment with key research objectives [21].

2) Focus Group Discussions:

To enrich data quality and encourage interactive dialogue, two focus group discussions are conducted with 5-7 participants each. Focus groups are particularly effective in generating insights from peer interactions and uncovering shared or contested viewpoints within the developer community [22].

3) Document Analysis:

Supporting data is collected through analysis of relevant industry documents, training manuals, and online developer forums focused on quantum computing. Document analysis adds context and enables verification of themes emerging from interviews and focus groups [23].

Data Analysis Methods

1) Thematic Analysis:

Data is analyzed using thematic analysis, a method suitable for identifying, analyzing, and reporting patterns (themes) within qualitative data [24]. The six-step process of thematic analysis involves familiarization with the data, initial code generation, theme searching, theme reviewing, theme defining, and report writing.

2) Coding Techniques:

Both manual and computer-assisted coding techniques are employed. Open coding is used initially to identify broad concepts, followed by axial coding to relate categories and selective coding to refine central themes [25]. Coding ensures systematic data organization and theme development grounded in participants' narratives.

3) NVivo Software Usage

NVivo 14 qualitative data analysis software supports efficient data management and enhances the transparency of the coding process. NVivo assists in coding large datasets, visualizing relationships between themes, and maintaining audit trails, thus increasing the study's analytical rigor [26].

Ethical Considerations

Ethical integrity is maintained by adhering to established research ethics protocols. All participants are provided with **informed consent forms** explaining the study's purpose, voluntary participation, and confidentiality assurance. Participants have the right to withdraw at any stage without any consequences. Anonymity is ensured by de-identifying data and using pseudonyms in reporting. Ethical clearance is obtained from the institutional ethics review board before data collection [27].

Trustworthiness and Rigor

To ensure rigor in qualitative research, the study addresses four key criteria: credibility, transferability, dependability, and confirmability [28].

- **Credibility** is established through member checking, where participants review and validate interview

summaries to ensure accurate representation of their views.

- **Transferability** is enhanced by providing rich, thick descriptions of participants' contexts, enabling readers to determine the applicability of findings to other settings.
- **Dependability** is ensured through a detailed audit trail documenting all methodological decisions and NVivo coding processes, facilitating future reproducibility.
- **Confirmability** is addressed by reflexivity, where the researcher maintains reflective notes to acknowledge and minimize personal biases during data collection and analysis.

This robust methodological approach ensures that the study generates trustworthy, contextually grounded insights into how software developers adapt to quantum computing architectural concepts.

Results and Findings

This section presents the key findings from the qualitative investigation into software developer adaptation to quantum computing architectural concepts. Using thematic analysis supported by NVivo 14, data collected from interviews, focus groups, and document analysis were coded and synthesized into **three overarching themes**, each containing sub-themes. These themes reflect cognitive, motivational, and contextual dimensions of the adaptation process, as outlined in the study's conceptual framework (Fig. 1).

Theme 1: Cognitive Adaptation — Navigating Conceptual Complexity

One of the most prominent themes was the mental transition from classical to quantum logic, which posed significant cognitive challenges. Developers expressed difficulty grasping abstract quantum concepts such as superposition, entanglement, and non-deterministic behavior.

"I've been programming for over a decade, but trying to understand quantum gates and qubits felt like starting all over again. It's not just syntax; it's a completely new way of thinking." — Participant 4

Sub-themes within this category included:

- **Cognitive Dissonance:** Many developers experienced confusion when trying to reconcile

classical computing logic with quantum principles.

- **Learning Curve Stress:** The steep learning curve often caused feelings of frustration and reduced motivation.

These findings align with Sweller's Cognitive Load Theory, which posits that learning is impeded when information complexity overwhelms working memory [15]. Figure 2 below illustrates how developers move through different phases of cognitive adaptation.

Theme 2: Motivational Adaptation — Purpose-Driven Engagement

Despite cognitive hurdles, many developers expressed a strong desire to engage with quantum computing due to personal interest, career advancement opportunities, or perceived future relevance.

"Quantum is the next frontier. If I don't learn it now, I'll be left behind professionally." — Participant 7

Sub-themes identified:

- **Intrinsic Motivation:** Developers driven by curiosity and challenge-seeking behavior.
- **Extrinsic Motivation:** Developers influenced by job market trends, employer encouragement, or academic requirements.
- **Perceived Utility:** Belief that quantum knowledge will be essential in future software development landscapes.

These motivational patterns are consistent with the **Technology Acceptance Model** [12], where perceived usefulness and personal relevance significantly impact adoption behavior.

Theme 3: Contextual Adaptation — Influence of Environment and Support Systems

The third major theme identified was contextual adaptation, highlighting how external factors such as organizational culture, access to resources, and peer support influenced the adaptation process.

"When I joined a quantum pilot project at work, everything became easier. I had people to talk to, real problems to solve, and that made a difference." — Participant 2

Sub-themes included:
- **Organizational Support:** Access to mentors, quantum projects, and time for learning.
- **Community Engagement:** Participation in open-source quantum forums, GitHub repositories, and online hackathons.
- **Educational Infrastructure:** Availability of hands-on tutorials, courses, and documentation was critical for learning.

These insights echo findings by Duncan and Chua [11], who argue that developer readiness is heavily influenced by institutional backing and available learning ecosystems.

Use of Diagrams and Models
To synthesize findings, Figure 2 presents the Developer Adaptation Trajectory, which integrates the three major themes (Cognitive, Motivational, and Contextual) into a developmental progression model. It depicts how software developers typically move from initial exposure to conceptual mastery through phases such as:
1. Initial Exposure (Overwhelm)
2. Early Engagement (Curiosity or Resistance)
3. Struggle Phase (Cognitive Dissonance)
4. Support-Seeking (Contextual Help)
5. Skill Integration (Internalization)

Each phase is influenced by different combinations of internal and external factors, reinforcing the interconnectedness of the adaptation dimensions.
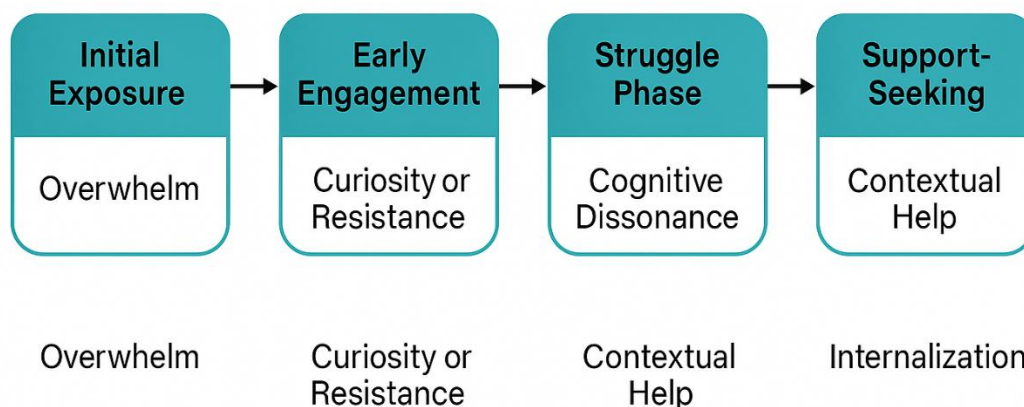

Fig. 2 Developer Adaptation Trajectory

Figure 2 illustrates the Developer Adaptation Trajectory, outlining the typical stages software developers experience when adapting to quantum computing architectural concepts. The trajectory consists of five sequential phases: Initial Exposure, where developers often feel overwhelmed by unfamiliar quantum concepts; Early Engagement, characterized by curiosity or initial resistance; Struggle Phase, where cognitive dissonance and learning difficulties peak; Support-Seeking, where developers actively seek external help through communities, mentors, or educational resources; and finally, Skill Integration, where acquired knowledge is internalized, and developers gain functional competence. This staged model visually represents the dynamic and progressive nature of adaptation, emphasizing how both internal motivation and external support facilitate successful transition into quantum computing.

Summary of Key Patterns
The analysis revealed consistent patterns across participants highlighting three dominant adaptation dimensions—cognitive, motivational, and contextual. Developers commonly faced significant cognitive challenges, particularly in transitioning from classical deterministic thinking to quantum probabilistic models, leading to initial confusion and frustration. Simultaneously, motivational factors played a crucial role, with many developers expressing a blend of intrinsic curiosity and extrinsic career-oriented incentives driving their engagement with quantum

concepts. Contextual factors, such as access to supportive workplace environments, community networks, and educational resources, were pivotal in either accelerating or hindering the adaptation process. These patterns collectively underscore that

successful adaptation to quantum computing is not solely a function of individual effort but is deeply influenced by a combination of personal motivation, cognitive readiness, and the surrounding support structures.

Table 1: Summary of Key Themes, Sub-Themes, and Supporting Evidence from Developer Adaptation Narratives

Theme	Sub-Themes	Sample Evidence
Cognitive Adaptation	Cognitive dissonance, learning curve stress	"It's not just new tools—it's a new mental model."
Motivational Adaptation	Intrinsic/extrinsic motivation, perceived utility	"I'm learning it to future-proof my career."
Contextual Adaptation	Organizational support, community engagement	"Online forums helped me debug quantum code for the first time."

Table 2: Thematic Summary of Cognitive, Motivational, and Contextual Adaptation Dimensions with Key Findings and Participant Quotes

Theme	Sub-Themes	Key Findings	Supporting Quotes
Cognitive Adaptation	- Cognitive Dissonance- Learning Curve Stress	Developers experience mental struggle transitioning from classical to quantum paradigms.	*"It's like unlearning everything I knew and starting fresh with a new mindset."* — Participant 6
Motivational Adaptation	- Intrinsic Motivation- Extrinsic Motivation- Perceived Utility	Motivation is driven by curiosity, career goals, and perception of quantum computing's future relevance.	*"Quantum feels like the next big thing, and I don't want to miss out on it."* — Participant 9
Contextual Adaptation	- Organizational Support- Community Engagement- Educational Resources	Support systems like workplace projects and peer networks ease adaptation struggles.	*"Being part of a developer community really helped me overcome early frustrations."* — Participant 3

Discussion

Interpretation of Results

The findings of this study reveal that software developers experience a multidimensional adaptation journey when engaging with quantum computing architectural concepts. The process involves complex cognitive transitions, marked by the need to unlearn deterministic logic and embrace probabilistic reasoning, which aligns with the anticipated cognitive barriers of disruptive technology adaptation. Simultaneously, motivational drivers, including curiosity, professional growth, and future job market relevance, motivate developers to persist through these difficulties. Additionally, the presence or absence of contextual enablers, such as organizational initiatives, community interactions,

and access to practical learning resources, significantly shapes the pace and success of adaptation. These results suggest that adaptation is an evolving process influenced by internal factors (mindset and motivation) and external environments (support systems and resources).

Linkage with Existing Literature

These findings resonate with previous technology adoption studies, such as the Technology Acceptance Model (TAM), which emphasizes perceived usefulness and ease of use as key determinants of adoption behavior [12]. However, this study expands on TAM by highlighting the cognitive complexity unique to quantum computing, as described in Cognitive Load Theory (CLT) [15]. The frustration

and mental load reported by participants affirm that quantum computing introduces a conceptual shift not commonly observed in the adoption of incremental technologies. The study also supports insights from Diffusion of Innovations Theory, particularly the role of early adopters and social systems in facilitating adaptation [14]. Compared to prior work that largely quantifies adoption trends [6], this qualitative research contributes nuanced, experience-based evidence of how individual, social, and organizational factors interact in this emerging technological landscape.

Implications for Theory and Practice

Theoretically, this study suggests an extension of existing adoption models by incorporating cognitive readiness as a critical precursor to technology acceptance, especially in highly abstract domains like quantum computing. From a practical standpoint, the study offers key recommendations for technology leaders and educational institutions: (1) develop phased learning programs that reduce cognitive load through incremental exposure; (2) foster mentorship and peer learning environments within organizations; (3) invest in practical, hands-on resources that bridge theoretical knowledge with real-world applications; and (4) align career development frameworks to include quantum computing as a growth path. These implications are particularly relevant as industries begin to integrate quantum solutions into business processes, requiring an adaptable and future-ready workforce.

New Insights in Computer Science Context

This research contributes new qualitative insights to the field of computer science by highlighting the human dimension of adapting to quantum computing—a subject traditionally dominated by hardware and algorithmic discussions. It brings forward the developer-centric perspective, identifying not only technical barriers but also emotional, cognitive, and social factors affecting adaptation. Moreover, it uncovers the critical role of contextual ecosystems, suggesting that environments rich in collaborative opportunities and accessible educational materials can significantly accelerate developer readiness for quantum transitions. This

human-centered knowledge is essential for shaping inclusive, realistic roadmaps for the adoption of quantum computing in the broader computer science domain, ultimately supporting smoother integration into mainstream software development practices.

Conclusion
Summary of Main Findings

This qualitative study explored the multifaceted adaptation process of software developers to quantum computing architectural concepts. The results revealed three dominant themes shaping the adaptation journey: cognitive adaptation, involving significant mental shifts from classical to quantum paradigms; motivational adaptation, driven by personal curiosity, professional advancement, and perceived technological relevance; and contextual adaptation, where organizational support, community engagement, and access to resources play crucial roles. The findings emphasize that adaptation is a gradual, multi-phase process shaped by both internal attitudes and external environments.

Contribution to Knowledge

The study contributes to the expanding body of knowledge by addressing a critical gap in quantum computing research—focusing on the human and professional adaptation of software developers rather than purely technical or algorithmic advancements. By integrating perspectives from Cognitive Load Theory, Technology Acceptance Model, and Diffusion of Innovations Theory, the research proposes a nuanced, developer-centered conceptual framework. This study enriches the discourse in computer science by introducing qualitative, experience-based evidence on how developers navigate the unique complexities of quantum computing, offering valuable insights for educators, industry leaders, and policymakers.

Limitations of the Study

Despite its contributions, the study has some limitations. The participant pool, while diverse, was relatively small and limited to specific professional settings, which may affect generalizability. The study's reliance on self-reported data may introduce subjectivity or recall bias. Additionally, the rapidly

evolving nature of quantum computing means that the developers' perceptions captured in this research may shift over time as tools, resources, and industry practices develop further.

Suggestions for Future Research

Future research should consider expanding the participant base to include a more globally diverse sample of software developers, including those in academic, startup, and corporate environments. Longitudinal studies are recommended to track evolving adaptation experiences over time, especially as quantum computing becomes more mainstream. Moreover, comparative studies between software developers and other professional groups (e.g., data scientists, system architects) could provide broader insights into adaptation patterns. Finally, future studies could explore intervention strategies, such as tailored training programs or collaborative learning models, to empirically test methods that ease the transition to quantum computing architectural concepts.

REFERENCES

[1] M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information*, 10th ed., Cambridge University Press, 2010.

[2] J. Preskill, "Quantum Computing in the NISQ era and beyond," *Quantum*, vol. 2, p. 79, 2018.

[3] S. Arute et al., "Quantum supremacy using a programmable superconducting processor," *Nature*, vol. 574, pp. 505–510, 2019.

[4] E. Pednault, J. A. Gunnels, G. Nannicini, and R. Wisnieff, "Leveraging secondary storage to simulate deep 54-qubit Sycamore circuits," *arXiv preprint arXiv:1910.09534*, 2019.

[5] J. Williams, "Bridging the gap: Software developers and emerging technologies," *ACM Computing Surveys*, vol. 53, no. 6, pp. 1–32, 2021.

[6] S. Wang and M. Wang, "Technology adoption and adaptation: A systematic literature review," *Technological Forecasting and Social Change*, vol. 173, p. 121177, 2021.

[7] P. Campagne and L. Delfosse, "Challenges in Software Engineering for Quantum Computing," *IEEE Software*, vol. 39, no. 5, pp. 21–27, 2022.

[8] M. Pistoia, *Programming Quantum Computers: Essential Algorithms and Code Samples*, O'Reilly Media, 2021.

[9] M. Zalka and G. Smith, "Bridging Classical and Quantum Software Engineering," *Communications of the ACM*, vol. 65, no. 1, pp. 40–48, 2022.

[10] A. Gabor et al., "Teaching Quantum Computing to Computer Scientists," in *Proc. ACM ITiCSE Conf.*, 2020, pp. 263–269.

[11] R. Duncan and P. Chua, "Workforce Readiness for Quantum Computing: An Industrial Perspective," *IEEE Transactions on Engineering Management*, vol. 70, no. 2, pp. 445–453, 2023.

[12] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Quarterly*, vol. 13, no. 3, pp. 319–340, 1989.

[13] L. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: Toward a unified view," *MIS Quarterly*, vol. 27, no. 3, pp. 425–478, 2003.

[14] E. M. Rogers, *Diffusion of Innovations*, 5th ed., Free Press, 2003.

[15] J. Sweller, "Cognitive load theory and educational technology," *Educational Technology Research and Development*, vol. 58, no. 2, pp. 257–271, 2010.

[16] S. Krantz, *Quantum Computing: A Gentle Introduction*, 2nd ed., MIT Press, 2023.

[17] P. W. Shor, "Algorithms for quantum computation: Discrete logarithms and factoring," in *Proc. 35th Annual Symp. Foundations of Computer Science*, 1994, pp. 124–134.

[18] A. Montanaro, "Quantum algorithms: An overview," *npj Quantum Information*, vol. 2, no. 1, pp. 1–8, 2016.

[19] J. Creswell and C. Poth, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*, 4th ed., Sage Publications, 2018.

[20] S. J. Tracy, *Qualitative Research Methods: Collecting Evidence, Crafting Analysis, Communicating Impact*, 2nd ed., Wiley-Blackwell, 2020.

[21] I. Seidman, *Interviewing as Qualitative Research: A Guide for Researchers in Education and the Social Sciences*, 5th ed., Teachers College Press, 2019.

[22] D. L. Morgan, "Focus groups as qualitative research," *Qualitative Research Methods Series*, vol. 16, pp. 1–29, 1997.

[23] G. Bowen, "Document analysis as a qualitative research method," *Qualitative Research Journal*, vol. 9, no. 2, pp. 27–40, 2009.

[24] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77–101, 2006.

[25] A. Strauss and J. Corbin, *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 3rd ed., Sage Publications, 2008.

[26] QSR International, *NVivo Qualitative Data Analysis Software (Version 14)*, QSR International, 2023.

[27] B. G. Glaser and A. L. Strauss, *The Discovery of Grounded Theory: Strategies for Qualitative Research*, Aldine, 1967.

[28] L. Lincoln and E. Guba, *Naturalistic Inquiry*, Sage Publications, 1985.

[29] J. Miles, *Qualitative Data Analysis: A Methods Sourcebook*, 4th ed., Sage Publications, 2020.

[30] M. Bazeley and K. Jackson, *Qualitative Data Analysis with NVivo*, 3rd ed., Sage Publications, 2019.

[31] D. Silverman, *Interpreting Qualitative Data*, 6th ed., Sage, 2021.