

Employability and Career Intentions of Quantum Computing Graduates Investigated by a Clustering Algorithm

Zhougeng Lin^{1,a,*}

¹School of Management, Shenzhen Polytechnic University, Shenzhen, China

^aderek.lin@msn.com

*Corresponding author

Abstract: This study empirically investigates the career intentions and employability perceptions of graduates specializing in the emerging field of quantum computing. Against the backdrop of a rapidly expanding quantum technology sector, which faces a critical shortage of qualified professionals, this research addresses a significant gap in understanding the human capital pipeline. A structured survey was administered to graduates from quantum computing-related programs, with the collected data subjected to both descriptive statistical analysis and advanced machine learning techniques, specifically K-means clustering, to identify latent patterns and profiles. The analysis reveals a complex landscape of graduate preparedness and aspiration. While a majority express a strong intention to pursue careers directly related to their quantum specialization, a significant proportion experience considerable anxiety and uncertainty regarding their job prospects. The clustering analysis delineates three distinct graduate profiles: the confident specialists, who are well-aware and focused; the anxious explorers, characterized by high pressure and uncertainty; and the pragmatic learners, who adopt a flexible, skill-oriented approach. Key findings indicate that perceived gaps in specialized skills and practical experience are primary factors hindering employment confidence. The study concludes that bridging the gap between academic training and industry requirements is paramount. It proposes a multi-faceted set of recommendations targeted at both higher education institutions and graduates themselves. These include enhancing curricula with practical, industry-relevant modules, strengthening university career support systems, and encouraging proactive career planning. This research contributes to the broader discourse on workforce development in high-technology fields by providing a nuanced, data-driven perspective on the factors shaping the career trajectories of quantum computing graduates.

Keywords: Career preferences; employability; quantum computing; K-means clustering

1. Introduction and Methodology

Global job listings in quantum technologies have surged approximately 180% from 2020 to 2024 [1]. The global shortage of qualified quantum professionals is a critical bottleneck for the industry's growth, with demand significantly outstripping supply across both academia and the private sector [2].

For every qualified quantum professional, there are roughly three open positions [3]. Industries such as cybersecurity, finance, pharmaceuticals, and logistics are actively seeking individuals who can harness the power of quantum theories [4]. Government programmes—such as the UK National Quantum Technologies Programme—also continue to expand [5]. The EU's Quantum Flagship program funds research and training initiatives aligning with industry workforce needs [6].

This study examines the career intentions of quantum computing graduates by means of a structured questionnaire, building on existing literature to ensure the validity and applicability of the results. Data are analyzed to identify prevailing employment trends and challenges, leading to practical recommendations that offer theoretical and practical support for graduates in this emerging field.

2. Survey Design

This research aims to identify key issues and influencing factors in the job search process of recent quantum computing graduates as demonstrated in the Figure 1. Data are analyzed to provide actionable

suggestions for academic institutions to improve career guidance. The survey design involved the following steps:

- (1) Determining sample composition in terms of student background and gender distribution.
- (2) Investigating employment pressure, challenges, expectations, and career orientation.
- (3) Analyzing influencing factors.
- (4) Proposing evidence-based recommendations.

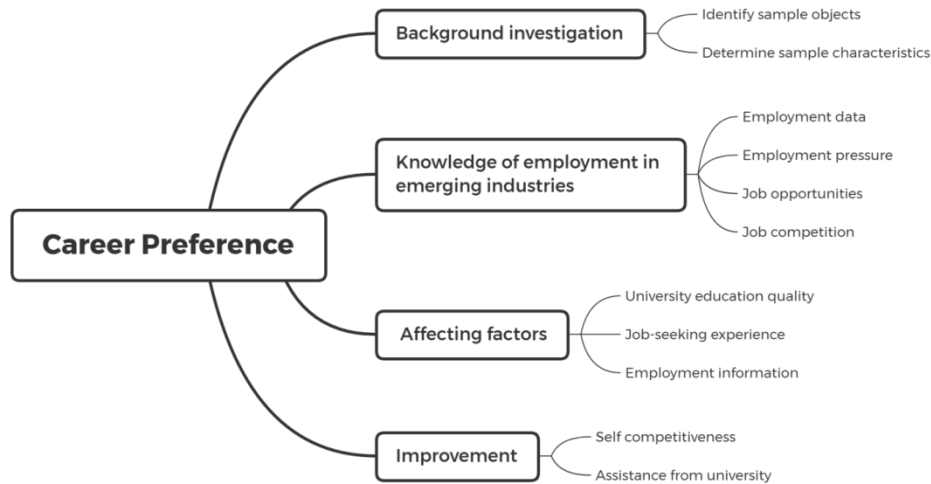


Figure 1: Survey Design Logic

Employment intention among university students encompasses multiple dimensions, including perceived pressure, career expectations, relevance of specialized coursework, and job search difficulties. This study focuses on identifying the principal factors affecting the employment intentions of recent quantum computing graduates.

In the literature review section, relevant publications and online resources were consulted to understand the context of employment challenges for quantum computing graduates. In the interviews section, discussions were conducted with graduates from quantum computing programs. In the questionnaire section, a total of 265 questionnaires were distributed randomly via WeChat to recent graduates; responses were compiled and analyzed to identify key issues.

3. Results and Analysis

Career paths of this industry include quantum data Scientist, quantum applications developer, quantum researcher, etc [7]. Quantum algorithms are revolutionizing computational chemistry, opening up new career paths for graduates in chemical and pharmaceutical industries [8]. Post-quantum cryptography (PQC), mathematicians, cryptographers, and security analysts with quantum-savvy skill sets are in exceptionally high demand [9].

3.1. Respondent Background

The study targeted graduates with degrees related to quantum computing. There are 265 valid questionnaires collected from the survey and the survey response rate is 89%. Among the respondents, the Table 1 shows that 59.32% are male and 40.68% are female. Graduates might work in existing or newly established quantum research and development (R&D) groups, or as a quantum software developer [10].

Table1: Gender distribution

Option	Proportion
Male	59.32%
Female	40.68%

3.2. Awareness of Employment Situation

As shown in Table 2, 27.12% of respondents reported being "very aware" of the employment situation, 30.51% were "aware," 37.29% were "slightly aware," and 5.08% were "unaware." This indicates that the majority of graduates have some understanding of current employment conditions.

Table 2: Graduates' awareness of employment situation

Option	Proportion
Very aware	27.12%
Aware	30.51%
Slightly aware	37.29%
Unaware	5.08%

3.3. Information Channels Used

Graduates today have access to multiple channels for obtaining employment information, such as job-search apps and career fairs. These tools offer considerable convenience and partially alleviate employment challenges.

According to Table 3, school-recruitment platforms (88.14%) and university career sessions (69.49%) were the most commonly used channels, followed by social websites (47.46%) and personal referrals (45.76%).

Table 3: Information Channels Used

Option	Proportion
University website	76.27%
School recruitment events	88.14%
University career sessions	69.49%
Personal recommendations	45.76%
Social networks	47.46%
General job fairs	27.12%
Corporate websites	25.42%

3.4. Perceived Employment Pressure

As illustrated in Table 4, 30.51% of graduates reported "very high" pressure, 35.59% reported "high" pressure, 20.34% reported "low" pressure, and 6.78% reported "no pressure." An additional 6.78% expressed general confusion. These results suggest that a significant proportion of graduates experience considerable pressure, possibly due to uncertainty about future employment.

Table 4: Factors Hindering Employment

Option	Proportion
Very high	30.51%
High	35.59%
Low	20.34%
None	6.78%
Confused	6.78%

3.5. Factors Hindering Employment

According to Table 5, the main factors cited by graduates were: lack of ability (42.37%), absence of career planning (32.20%), difficulty finding suitable positions (13.56%), and perceived policy shortcomings (8.47%). This indicates that many graduates feel underprepared in terms of specialized skills, which may undermine their confidence and competitive edge.

Table 5: Factors Hindering Employment

Option	Proportion
No career plan	32.2%
Lack of ability	42.37%

Lack of position		13.56%
Insufficient policy		8.47%
Other		3.39%

3.6. Career Expectations

As shown in Table 6, 55.93% of respondents hoped to work in a quantum-related field, 13.56% planned to pursue further education, 8.47% intended to start their own business, and 22.03% remained undecided. This suggests that while most prefer jobs related to their major, a notable proportion are considering alternatives or are uncertain.

Table 6: Career Expectations

Option	Proportion
Further education	13.56%
Employment	55.93%
Entrepreneurship	8.47%
Undecided	22.03%

3.7. Influence of Specialized Courses

According to Table 7, 27.12% of respondents believed specialized courses had a "very large" influence on employment prospects, 47.46% reported "large" influence, 15.25% "small," and 10.17% "none." Overall, most graduates consider their specialized training relevant to employment.

Table 7: Perceived Influence of Specialized Courses

Option	Proportion
Very large	27.12%
Large	47.46%
Small	15.25%
None	10.17%

3.8. Improving Core Competitiveness

As indicated in Table 8, graduates identified reliable specialized skills (86.44%) and practical experience (86.44%) as the most important factors for enhancing competitiveness, followed by public course knowledge (77.97%) and social communication skills (74.58%).

Table 8: Factors for Improving Core Competitiveness

Option	Proportion
Specialized skills	86.44%
Scientific knowledge	69.49%
Public courses	77.97%
Practical experience	86.44%
Social skills	74.58%
General knowledge	45.76%
Other	5.08%

3.9. Desired University Support

As shown in Table 9, graduates expressed strong interest in the following forms of university support: more specialized skills training (88.14%), employment training (77.97%), increased internship opportunities (74.58%), and interview preparation (62.71%). This reflects a desire for comprehensive, practice-oriented career support.

Table 9: Expected University Support

Option	Proportion
Internship opportunities	74.58%
Specialized training	88.14%
Employment training	77.97%
Interview training	62.71%
Other	10.17%

Therefore, 55.93% of quantum computing graduates prefer employment related to their major, and 94.92% are aware of the challenging job market. Over 70% rely on social networks, school recruitment, and personal referrals for job information. A majority report high levels of employment-related stress, likely due to increased graduate numbers and saturated demand. Strong foundational skills and practical experience are considered vital for competitiveness, indicating self-perceived skill gaps. Students desire more practical training, skill development, and career guidance from universities to enhance employability.

3.10. K-means Clustering Analysis of Graduate Profiles

K-means clustering aims to partition the respondents into distinct graduate groups based on their preference patterns, revealing latent profiles that might not be apparent from univariate analysis.

The analysis utilized the scikit-learn library in Python. Several key variables from the survey were selected as features for the clustering algorithm to capture graduates' attitudes and perceptions: awareness of employment situation, perceived employment pressure, perceived influence of specialized courses and career expectation. These variables were standardized to ensure each feature contributed equally to the distance calculations. The Elbow method was used to determine the optimal number of clusters $K=3$ to provide a good balance between cluster cohesion and distinctness. The algorithm is coded in Python, while the parameters are set as following.

```
career_intentions_kmeans = KMeans(
    n_clusters=3,      # Number of clusters (k)
    init='k-means',   # Smart initialization
    max_iter=300,     # Maximum iterations
    tol=1e-4,         # Tolerance for convergence
    random_state=42   # Reproducibility
)
```

The objective function is coded as following.

```
career_intentions_wcss = career_intentions_kmeans.inertia_
```

The distance update function is coded as following.

```
for i in range(career_intentions_kmeans.n_clusters):
    cluster_points = X[labels == i]
```

The squared Euclidean distance between a career intention data point $\phi(x_i)$ and a cluster centroid μ_h in the feature space can be computed using the kernel:

$$\|\phi(x_i) - \mu_h\|^2 = K(x_i, x_i) - \frac{2}{n_h} \sum_{\phi(x_j) \in S_h} K(x_i, x_j) + \frac{1}{n_h^2} \sum_{\phi(x_j), \phi(x_m) \in S_h} K(x_j, x_m)$$

where n_h denotes the number of points in cluster h , and S_h is the set of points in cluster h . The

kernel-based distance is to be minimized.

The algorithm partitioned the respondents into three distinct clusters, each representing a unique graduate profile.

(1) The confident specialists

This group exhibits high awareness of the employment situation and perceives a strong influence of their specialized courses on employment prospects. While they feel moderate to high employment pressure, their career expectation is strongly oriented towards working in the quantum field. They are characterized by a clear focus and confidence in their domain-specific skills.

(2) The anxious explorers

Members of this cluster report the highest levels of employment pressure. Their awareness of the job market is varied, and they are uncertain about their career path, with a significant portion being undecided or considering alternatives to core quantum roles. This group likely feels underprepared and experiences significant anxiety about their future.

(3) The Pragmatic Learners

This group demonstrates moderate awareness and feels lower pressure compared to the anxious explorer group. They acknowledge the importance of their specialized training but are more open to diverse career outcomes, including further education. Their approach is pragmatic, focusing on skill acquisition and keeping options open.

4. Challenges and Recommendations

4.1. Identified Challenges

(1) Low Confidence in Specialized Skills

Results indicate that many graduates feel underprepared for recruitment processes, which often assess cultural knowledge, physical fitness, and specialized competence—particularly in competitive sectors like state-owned enterprises.

(2) High Employment Pressure

Expansion of higher education has increased the supply of graduates, while employment demand has not kept pace. This mismatch is exacerbated in high-demand fields like quantum computing, where even top graduates face intense competition.

(3) Curriculum Gaps

Current quantum computing programs tend to emphasize theoretical training, with limited elective options and practical modules. This may leave graduates underprepared for industry expectations.

4.2. Recommendations

After analyzing employment intention of fresh graduates from quantum, in order to overcome restrictions and problems, both graduates themselves and the school should make joint efforts.

4.2.1. Enhance Specialized and Practical Training

During study, students should focus on learning and developing practical skills, apart from learning their own majors, they should know about other hot majors to improve specialized skills and abilities so as to create more opportunities for themselves. Here are some suggestions:

(1) Consider the richness of future and cultivate a heart of learning so as to learn more knowledge. Every one should be keen on their majors for every major has its unique advantage. The most widely used quantum programming tools in 2025 include: Qiskit (IBM), Cirq (Google), PyQuil (Rigetti) and Python, while Python remains the dominant language [11]. The emergence of quantum software engineering as a discipline underscores the need for graduates skilled in hybrid quantum-classical programming, algorithm design, and software verification [12]. The intersection of quantum computing and machine learning presents a rapidly growing niche, demanding a unique blend of skills in both domains [13]. Quantum hardware engineering requires a deep understanding of condensed matter physics, electronics, and cryogenics, highlighting a specialized and high-demand career track for

graduates [14]. Cloud-based quantum computing services like Amazon Braket provide accessible platforms for students and researchers to experiment with real quantum processors [15]. The integration of quantum computing with cloud infrastructure is creating new service models and career opportunities in the information technology sector.

(2) Make study plans and goals, and don't pay too much attention to recreational activities. Plans and goals are always reliable evidence of one's progress. It is indispensable to make plans and goals to learn professional knowledge well, students should do homework carefully and make feasible plans to find a balance between entertainment and study. Effective industry-academia collaborations are pivotal in refining quantum computing curricula to better align with the practical needs of the evolving job market, ensuring graduates possess relevant skills [16].

4.2.2. Improve University Employment Support Systems

In the process of employment education, universities and colleges play an important role. The number of fresh graduates from quantum is increasing year by year and the competition of employment opportunities is fierce, so fresh graduates from quantum suffer from great employment pressure. Quantum computing professionals have ample opportunities to choose between day-rate contracting, fixed-term engagements, or permanent roles [17]. Therefore, the school should take the improvement of the employment service system as a priority in the work, change the traditional ideas, and strengthen communication with the society and exchange of information. Here are some suggestions:

(1) Establish employment guidance system, including a well-established employment information system to update the information of job markets in time. This system should ensure the real-time release of employment information of employers, the screening and connection of two-way school information, and the accuracy of graduate employment information[4]. Top employers increasingly value real-world demonstrations of skill, such as the Certifications from platforms like IBM's Quantum Developer Certification is helpful [18]. The vibrant open-source ecosystem is crucial for the growth of quantum computing, lowering the barrier to entry and fostering collaboration and innovation [19].

(2) Open APP for online interview. Online interview can provide more employment choices. Besides, according to the research of present job hunting APP, students can understand introduction, recruitment and index of enterprises online, universities and colleges can invite a lot of enterprise to hold online recruitment information sessions, and students can learn more knowledge of employment through these sessions; at the same time, online sessions not only broaden the students' employment channels, but also remit the employment pressure.

4.2.3. Encourage Early Career Planning

Quantum technology is projected to create a significant number of new jobs in sectors ranging from finance to pharmaceuticals by 2035, necessitating proactive workforce planning [20]. It is suggested that fresh graduates from quantum related courses should prepare career planning in advance. Face the fierce competition in the employment situation, if you want to successfully find a job upon graduation, you should think carefully about whether your employment expectations are too high or not, consider your future work based on reality, and make an appropriate career plan based on your ability when choosing a job. Here are some suggestions:

For students, they should know that students major in quantum can also be free from the restriction of profession. For example, quantum refers to quantum hardwares and softwares, financial modeling, medicine discovery and logistics optimization, therefore, there are a lot of jobs for choosing. Students should understand their own interest in this major and prepare their own career planning in advance.

For universities and colleges, they should establish a complete employment guidance and career planning agency, which can assess and cultivate graduates' vocational abilities, help them make the right career choices, and guide them to find the right job-hunting methods and make lifelong career planning. Career planning courses can also be set up to enable students to better find their own career paths, make more suitable employment choices and career development plans.

5. Conclusion

This study provides a comprehensive empirical analysis of the career preferences and employability challenges faced by quantum computing graduates, offering critical insights into workforce development within this emerging high-technology field. By integrating descriptive statistics with advanced machine learning techniques, specifically K-means clustering, the research moves beyond

superficial trends to reveal the nuanced profiles that characterize the graduate population. The identification of three distinct cohort: confident specialists, anxious explorers, and pragmatic learners—underscores the heterogeneity in graduate preparedness and career aspirations, which is often masked by aggregate data.

The findings highlight a central paradox: while industry demand for quantum talent significantly outstrips supply, a substantial proportion of graduates perceive significant skill gaps and experience considerable employment anxiety. This misalignment points to critical deficiencies not only in individual skill acquisition but also in the broader ecosystem connecting academic training with industry requirements. The strong consensus among respondents on the importance of practical experience and specialized skills, coupled with their demand for more robust university support, clearly indicates the areas requiring immediate intervention.

Theoretically, this study contributes to the literature on STEM workforce development by applying a novel clustering methodology to understand graduate trajectories in a nascent field. It demonstrates the value of person-centered analytical approaches in capturing the diversity of student experiences and outcomes. Practically, the findings offer actionable guidance for higher education institutions. There is an urgent need to modernize curricula by integrating industry-standard tools (e.g., Qiskit, Cirq) and emphasizing quantum software engineering and other application-oriented skills. Furthermore, universities must strengthen their career services by providing tailored guidance that addresses the specific needs of different graduate profiles, from the confident specialist seeking R&D roles to the anxious explorer requiring broader career counseling.

This study has several limitations. The sample, while insightful, is of a size that may limit the generalizability of the findings. Future research should aim for larger, longitudinal cohorts to track career paths over time. The reliance on self-reported data may also introduce bias. Subsequent studies could incorporate objective skill assessments and interviews with employers to triangulate findings.

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