LRZ Quantum User Study Report

Understanding User Needs and Requirements as a User-Centric Research Computing Centre

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Quantum computing is emerging as a transformative technology across academic and industrial domains. As a leading high-performance computing (HPC) center, the Leibniz Supercomputing Centre (LRZ) is expanding its portfolio to include hybrid quantum-classical computing services. To ensure these new services are accessible, relevant, and user-friendly, LRZ launched the Quantum User Study (QUS), a user-centered initiative to identify the needs, workflows, and expectations of both current and prospective quantum users. Through surveys, structured interviews, and stakeholder analysis, the study produced detailed user personas, use cases, and a set of functional and non-functional system requirements. These insights directly inform the design and development of the Munich Quantum Portal (MQP), LRZ's gateway to quantum resources. Participation in Friendly User Pilot Phases for early quantum hardware (Q-Exa, AQT) allowed users to test real devices, with feedback directly shaping interface design and system priorities. The findings outlined in this report offer practical guidance for building quantum services that align with evolving user demands and the realities of near-term quantum computing.

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I. INTRODUCTION

The Quantum User Study (QUS) is a key initiative aimed at understanding current and potential future users and their needs, in order to design and develop quantum computing services at LRZ. For the QUS, thorough stakeholder and market analysis are conducted to screen both the current and potential future user base. This assessment allows for a comprehensive understanding of how these quantum users interact with quantum system environments and their general research workflows. By understanding their requirements and needs, software development can be more precisely targeted, leading to the creation of better quantum services. These services aim to achieve higher user satisfaction, being more intuitive and easier to use, with minimal friction and simplified access. Additionally, regular feedback loops are implemented to continuously gather user input, ensuring that the services evolve in line with user expectations and technological advancements. This proactive approach not only enhances user experience but also helps in anticipating and meeting future demands effectively.

The goal of the QUS is to act as a comprehensive document, emphasizing the different user categories and personas. It also includes templates for documenting user needs and specifying user requirements, ensuring thorough and precise data capture. The QUS supports the development of LRZ services in quantum computing by collecting detailed user requirements. By collaborating with the LRZ quantum software development team, enhancing the user experience of the Munich Quantum Portal (MQP), a platform developed under the project Munich Quantum Software Stack (MQSS)[1,2], to access, submit jobs to, and retrieve results from the quantum computers available at LRZ. The study seeks to gather extensive requirements through an in-depth, collaborative process using both qualitative and quantitative information. With interviews and surveys, information and user data are gathered to develop user personas and use cases, which depict various user groups and guide the design process. The insights from the study are pivotal to the software development lifecycle, understand the market trends, increase user satisfaction and improve relevance and usability.

The motivation and goals of this study aims to foster innovation and diversity, cater to the broad range of needs and use cases within the research community. Key aspects include:

- Innovation: as a user-centric facility, the study focuses on providing cutting-edge quantum computing resources,
- Diversity: cater to the diverse needs and use cases,

- Usability: the platform will focus on creating a user-friendly, intuitive interface that is easy to navigate, understand and implement.
- Adaptability: users should be able to access different available systems. Adapting new features based on user feedback and requirements.
- Augmentation: the study will explore possibilities for integrating quantum computing with high-performance computing.
- Collaboration: building a synergetic ecosystem between different stakeholders – researchers, institutions, hardware providers, funding agencies to encourage knowledge sharing, innovation and exchange collective ideas to achieve scientific discovery and innovation while prioritizing user needs.

This report is structured as follows: this introduction highlights the motivation and objectives of the study. The section context provides a comprehensive overview of the quantum environment surrounding LRZ and further relates to other existing quantum studies. This is followed by a thorough analysis of the potential user groups and the broader user landscape. In the main section, the approach and methods for gathering detailed user data are described, including qualitative and quantitative techniques such as surveys and structured interviews. The results section details how users interact with the quantum system through various workflows, and highlights the identified user groups, user personas, and user requirements. These results are aimed at ensuring functional access, while also enhancing user experience and satisfaction with the system.

II. CONTEXT

A. Position of LRZ

LRZ is in a unique position, with years of experience as a computing facility primarily focused on HPC. It is now expanding into quantum computing, leveraging quantum hardware devices as accelerators and combining them with HPC. Existing expertise in both fields supports this transition.

The Leibniz supercomputing Centre is an IT service provider for research and has established partnerships within academia, particularly in Munich, Bavaria, and across Europe. With a network of over 100,000 students and scientific employees in academia and research, there is significant potential for new quantum users across various domain disciplines, as many have not previously been exposed and utilized quantum technologies.

This section highlights the scope and user base of the project which in turn explains the extent of the user study; namely the geographical location of LRZ, the quantum market environment, the involvement of project partners and collaborators, funding agencies, and the broader boundary conditions that set the context for the project.

Location plays a key role in understanding the user base. Situated in the Munich metropolitan area, surrounded by many research institutes, such as those from the Fraunhofer and Max-Planck society, as well as large universities (e. g. Technical University of Munich and Ludwig Maximilian University), the immediate demographic includes many quantum researchers from these institutions. However, looking beyond the local vicinity, there is significant potential for collaboration and fruitful partnerships with project partners across Bavaria and further on national and European level. Additionally, the location has influenced the selection of hardware and software vendors, as well as potential collaborators, aligning with local resources and expertise.

When it comes to quantum hardware, the strategy so far has been to make the cutting-edge and in-demand technology accessible to the users. The idea of ensuring the shortest path to adoption for the user community is reflected by the choice of concentrating the initial effort on systems based on superconducting qubits, like Q-Exa[3,4] and Euro-Q-Exa[5] and to extend to other qubit modalities like ion-trap[6,7] and neutral atoms[8,9]. It remains unclear as of now, whether a qubit modality will prevail in the future, or whether some of them will coexist for specific use cases or application areas. As a consequence, there is motivation in offering a broad portfolio of different technologies.

As depicted above, the project partners and collaborators also influence the core user landscape. At the local level, collaborations such as the development of the Munich Quantum Software Stack and involvement in the Munich Quantum Valley play a vital role in shaping most activities. On a larger scale, collaborations with companies exploring quantum technology could provide invaluable use cases and expand the reach into industry-focused applications, further enriching the ecosystem and ensuring that our initiatives remain aligned with both academic and practical advancements.

Funding agencies play a significant role in shaping the boundaries of the project. While funding allows for access to cutting-edge technology and supports ongoing research and development, it also comes with expectations regarding timelines and deliverables. This means balancing between fulfilling immediate project goals and allowing the flexibility to adapt the systems in response to evolving user needs.

In addition, the rapidly advancing quantum technologies and shifting academic and industrial landscape also influenced the scope of the study. Given the interdisciplinary nature of this field, there are users coming from diverse backgrounds - ranging from students to experienced researchers — which introduce a certain variability in the user interactions and pose a challenge in creating a universally accessible system.

Despite these limitations, the project benefits from strong collaborations with partner institutions and enjoys access to emerging technologies. The continuous refinement of quantum hardware, paired with evolving software tools, provides an interesting environment for testing user-system interaction. The feedback from these interactions is extremely valuable for not only the immediate system enhancements but also contributes in shaping the future trajectory of the emerging quantum computing suite. The colocation of quantum hardware and HPC systems enables new workflows.

B. Related Work

Existing quantum studies, such as The McKinsey quantum report 2024[10] titled "Steady progress in approaching the quantum advantage," highlights significant decline in private investments and increase in public funding for quantum technologies. It also highlights a competitive landscape of countries striving for leadership in quantum domain. IBM is a major player in superconducting qubits, with substantial research efforts underway in the US and China, and the EU trailing in third place. Start-ups were identified to be making significant strides in providing quantum services via cloud. Key applications of quantum technologies include optimization in various industries such as supply and logistics, finance (e. g., portfolio management), and medicine (e. g., drug and genomics discovery).

A relevant survey by Unitary Foundation's Quantum Open Source Software (QOSS) survey in 2023[11], provides a comprehensive overview of the current landscape and evolving trends within the quantum open-source community. According to the survey results majority of respondents belong to the category of researchers (53.8%), followed by developers, students and hobbists. Around 45% respondents did not have any background in quantum research. IBM Quantum remains the most popular cloud service, with 70% of respondents currently using it, followed by AWS Braket at 19%. In terms of software frameworks, Qiskit leads with 69% usage, followed by PennyLane at 29% and Google Cirq at 22.8%. Python emerged as the most popular programming language, with around 94% of participants using it. These findings have been congruent with the results of the own survey at LRZ, showing the widespread use of Qiskit and PennyLane. In the QuEra report[12], 927 people were surveyed over 2023 and 2024. Of these, 43% were from academia, 19% from quantum companies, and 13% from non-quantum companies. The rest comprised analysts/press (2%), enthusiasts (14.2%), and others (8.1%). One-third of the respondents were from the US, with a significant portion also from Europe. When asked about the most significant technical challenge, 33% cited scalability, 30% mentioned error and fault tolerance, 20% pointed to quantum hardware performance, and 9% identified quantum algorithm development. The survey highlights a dynamic and rapidly progressing quantum computing landscape, with significant enthusiasm tempered by technical challenges and the need for strategic investments. Organizations are encouraged to remain vigilant and proactive to harness the potential benefits of quantum technologies.

Most respondents primarily used classical computing, hybrid quantum-classical approaches, or had not used quantum computing yet. The main drivers were exploring new possibilities and opportunities, preparing for future quantum markets, and supporting existing research and development projects.

The Unitary Foundation's 2024 Quantum Open Source Software (QOSS) Survey**?** , third iteration of the survey provides a comprehensive overview of the demographics and preferences, needs and expectations of the respondents. The results of the survey provide insights into the user experiences and community engagement highlighting the need for strengthening the quantum open-source ecosystem and continued development of quantum technologies. Out of 807 respondents, 56.1% were from Classical Programming and Software Technologies, followed by Quantum Research (55.5%), Quantum Programming and Software Technologies (40.1%), Non-Quantum Research (14.1%) and others (6.3%). Geographically, the United States remains the most represented country, accounting for 24%, followed by Canada 12.7%, and other countries with significant representation such as India, Germany, United Kingdom and European and Asian countries. IBM quantum remains the most popular cloud service in 2024 survey results followed by Amazon Braket, Xanadu, Google and Microsoft's Azure Quantum. In terms of full-stack development platforms, IBM's Qiskit continues to leads with 74.1% usage, followed by Qiskit Aer (49.3%) and PennyLane (46.8%), cirq (24.2%), amazon-braket-sdk-python (17%). The results of the QOSS 2023 and 2024 results also highlight that respondents choice of preference for cloud services is influenced by the following factors such as: performance, ease of use of service, well-maintained service, proper documentation, price, integration with software stack and supportive community. For software development kits (SDKs), documentation is the most critical factor, followed by performance.

The QOSS 2024 survey also highlights algorithm development (56.3%), error correction (51.6%), application development (45.5%), quantum simulation/physics (40.7%), circuit development and optimization (34.2%) as the major areas of future development in quantum computing followed by hardware development (37.3%), error mitigation (31/1%), software engineering (26.6%), quantum information theory (26.5%), fundamental physics (17.7%), qubit characterization (14.4%) and others (2.1%). The survey also provides valuable insights regarding the needs of the quantum community, by emphasizing on the need for educational resources, training and networking opportunities for students, mentoring support for new programmers and fostering a more inclusive quantum ecosystem.

Through its Pilot programs, LRZ strives to be a user-centric research facility by understanding user needs and enhancing their experience through effective communication and consulting support. Additionally, LRZ offers a range of training and educational programs tailored to different proficiency levels in quantum computing, along with internships and mentoring opportunities for students interested in exploring various research challenges.

C. Stakeholder Analysis

In order to understand the users, an analysis and identification of different stakeholders and their relationship with the Quantum Computing and Technologies (QCT) department at LRZ was performed. The result of brainstorming activities can be seen in Figure 1.

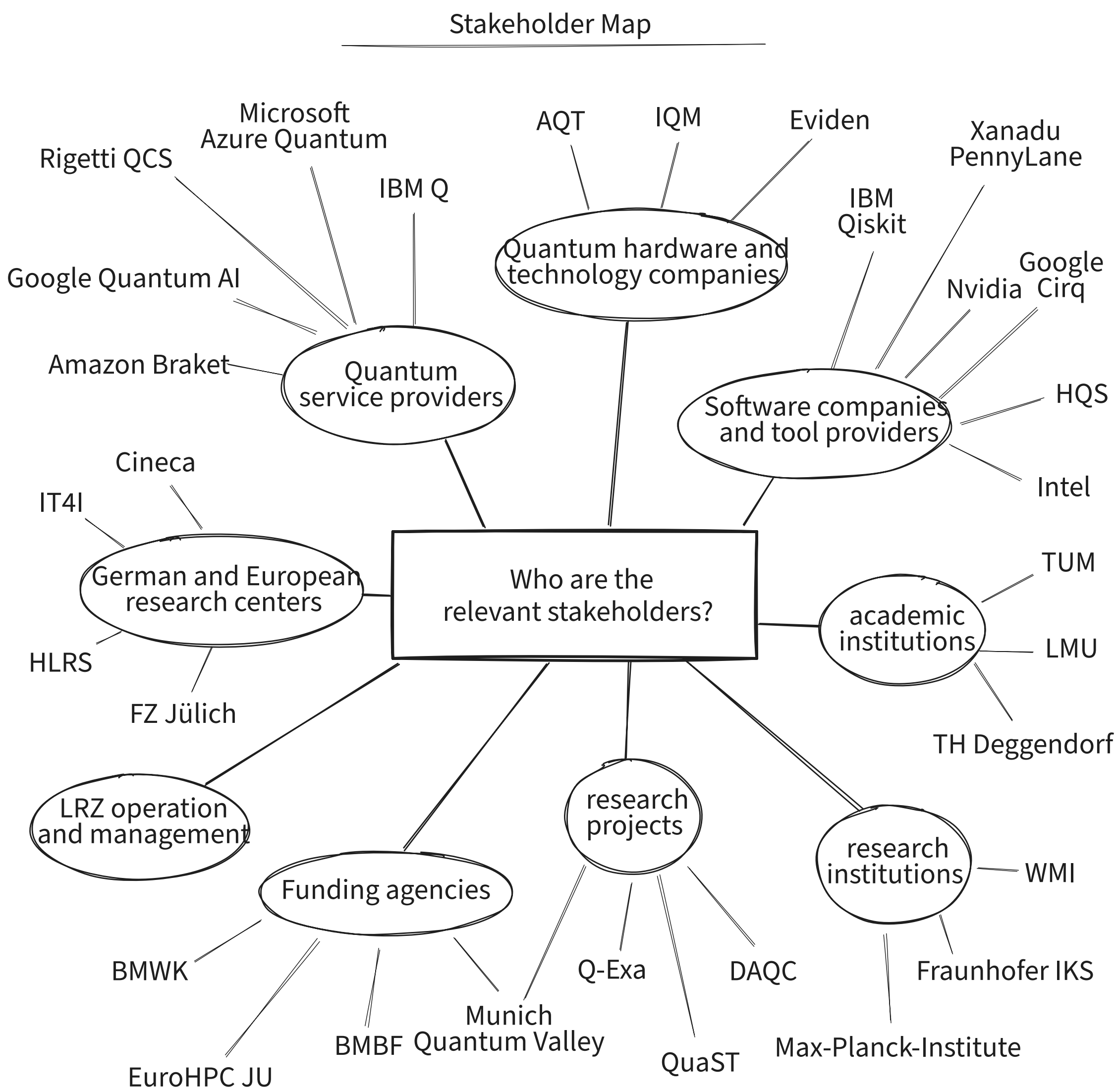

Figure 1. Stakeholder Map

Each of these institutions and groups play a crucial role in shaping quantum computing platforms. They help define the system requirements, from interface design, programming tools to performance metrics and algorithm efficiency. In the analysis, the stakeholders were iden-

tified and can be classified into different categories. Further, each category of a stakeholder group have different interaction or engagement with LRZ. Collaboration with different stakeholder groups is essential to accelerate the development of quantum solutions with multiple application possibilities.
The table highlights the different identified categories of stakeholder groups:

Stakeholders to monitor	**Stakeholders that enable**
• German and European research centres • Quantum service providers • Hardware technology companies • Software and infrastructure companies	• Quantum hardware companies • Software companies and tool providers • MQV, in particular MQSS development team
Stakeholders to inform	**Application end users**
• Funding agencies • Umbrella projects, e. g. MQV • LRZ management • General public	• Project partners and collaborators • Academic institutions • Research institutions

- **Stakeholders to monitor:** include other research institutions such as German or European research centres. Quantum hardware providers are also in this category, as they introduce new, innovative hardware products. Commercial quantum service providers and quantum software and infrastructure companies, which develop software and interfaces, are followed. Those are constantly monitored in regard to their newest developments.

- **Stakeholders to inform:** include the general public and interest groups, as well as funding agencies that support different projects and possible collaborations. There are regular meetings with different consortium groups and discussion on research progress, updates and setting targets for next phases.

- **Stakeholders that enable** are those who provide services such as toolkits or software frameworks. This category also includes hardware providers who grant access to their hardware, software developers who assist in developing relevant infrastructure, and system administrators. These stakeholders set the technical requirements, offer technical specifications and define the boundaries and constraints within which the system operates.

- **Application end users** are the user group interacting with the quantum system. They access the system in various ways, often with a specific research problem or question in mind. This group spans different disciplines, with most problems falling within the quantum optimization area. These users come with different levels of expertise: beginners or quantum enthusiasts trying to learn and explore new things, or experts with several years of experience with the domain.

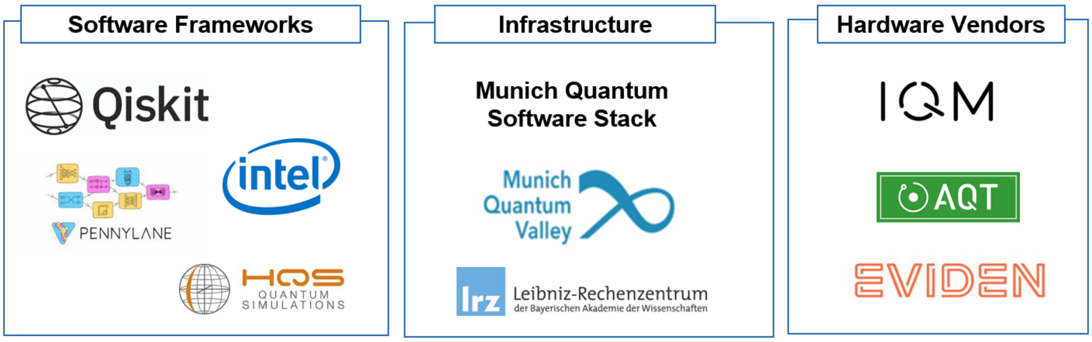

Figure 2. Stakeholders that enable

Application end users

The application end users can be categorized into the different groups with specific characteristics:

1. **Test and Pilot users**

   These users interact with new systems, providing feedback

   (a) Characteristics: Novice – Intermediate – Expert Knowledge

   (b) Interaction or Engagement:

      - Provide feedback about the quantum systems, improve usability, interfaces, documentation and workflows
      - Design user guide manuals, tutorials and workshops
      - Effective implementation and deployment of user centric features

2. **Project Partners and Collaborators**

   These users are engaged in project collaborations with specific goals and purposes defined by the project.

   (a) Domain expertise: Intermediate to advanced
   (b) Interaction or Engagement:
      - Define user requirements
      - Collaborations
      - Industry applications

3. **Academic Institutions**

   This group represents the largest potential user base. Currently, they do not use quantum computers, but as quantum technology matures and becomes more relevant, they may seek access.

   (a) Characteristics: Academic Users
   (b) Interaction or engagement: Drive research and quantum training and education

4. **Research Institutions**

   This group includes institutions theorizing with specific research problems or goals in mind, or those with specific use cases for quantum computing.

   (a) Characteristics: Users with specific goals and use cases
   (b) Interaction or Engagement: Feedback

Common observations from users across these user categories:
Based on the non-technical findings of the study, it can be noted that most users do not have a background in quantum mechanics; instead, they come from different field of domains such as computer science, mathematics, engineering or statistics. They encounter challenges in understanding the underlying physics and conducting additional research on the subject. Quantum technologies are a relatively new domain, with most of the participants having less than 1.5 years of experience. Overall, most of the users are comfortable with using Qiskit, describing it as beginner-friendly and well-documented software framework.
The interaction between the users and the quantum computing platform is designed as a dynamic and continuous process that is sensitive to user needs. It revolves around the exchange of user input — primarily their needs and requirement — and the system's corresponding output in the form of features and functionalities tailored to meet those needs. This approach ensures that the platform remains adaptable and continually improves in accordance with the user expectations.
User, such as researchers, developers, and students, provide specific inputs related to their

work and pain points in quantum computing, ranging from requests for enhanced system performance, ease of use of the platform, different modalities of the quantum systems, and the availability of specific information about the systems. For example, a research associate might request extensive information about the system, like the qubit connectivity, error rates, and the telemetric readings of the surroundings; while a student may just require a clearer user interface to better interact with the platform.

D. User System Interaction

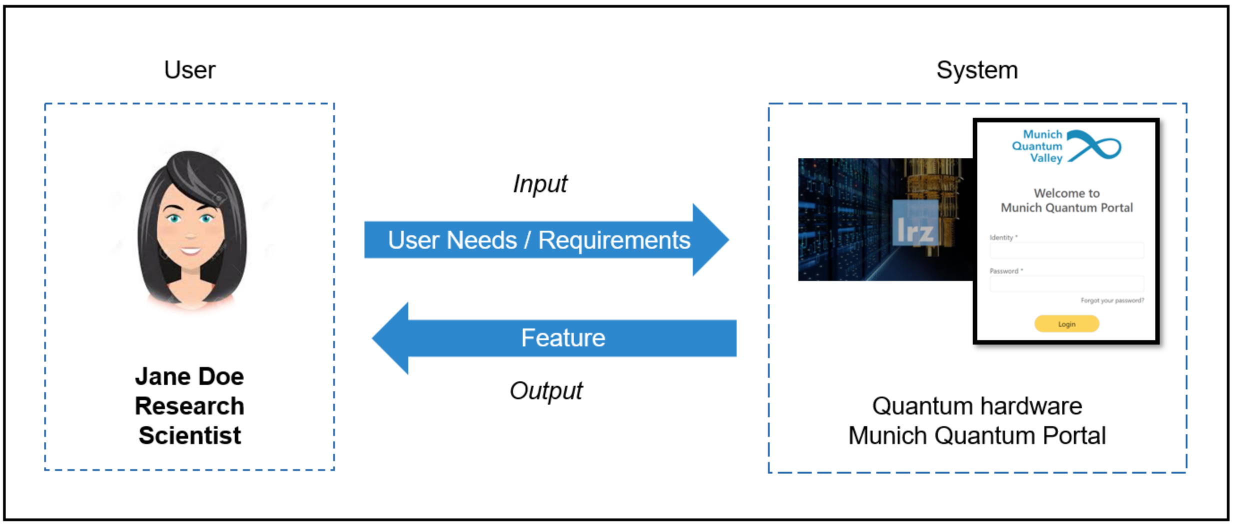

Figure 3. User-system interaction

The system evolves by incorporating features that address these requests. This feedback loop ensures that user requirements translate directly into system improvements. The system is continuously refined based on ongoing feedback, which ensures that it not only meets the immediate user needs but also anticipates future requirements as user interaction deepens. The system is designed with the broadness of the user landscape in mind, allowing users to customize their interactions according to their expertise. This customizability allows both novice and advanced users to extract value from the platform, making it a versatile tool for research and learning. In an abstract sense, examining the application end users reveals interactions between them and the system, whether it be the quantum ecosystem, a web portal, or the hardware device. These interactions and their nature are currently unknown and need to be explored.

Generally speaking, as illustrated in Figure 3 showing user and system interaction, the user is depicted on the left side, representing the person needed to be understood more of their deeply—their motivations, goals, and problems. The arrow pointing to the system represents the user needs and requirements, which are their demands or expectations from the system. Users approach the system with certain expectations based on their previous experiences, and these experiences must be captured as feedback to enhance the design process. The system encompasses the service, web portal, quantum hardware, or the entire quantum ecosystem, all of which need to be described in detail. The arrow returning from the system symbolizes the features and functionalities it will provide, or the feedback it will deliver based on user input. The system can be well-defined, encompassing expected functionalities, a quantum hardware system with an anticipated hardware topology, or the Munich Quantum Portal, which is the web portal and primary user interface. Anything the system provides back to the users — whether it be a circuit or a feature like a visual popup for help — needs to be monitored to ensure it meets user expectations regarding quality, quantity, ease of use, and access modality.

The central question in this interaction remains the user themselves. Additionally, potential future users must be considered: how they are shaped, where they come from, what they work with, and what problems they face. These aspects need to be identified through this user assessment process.

III. APPROACH AND METHODS

A. Research Strategy

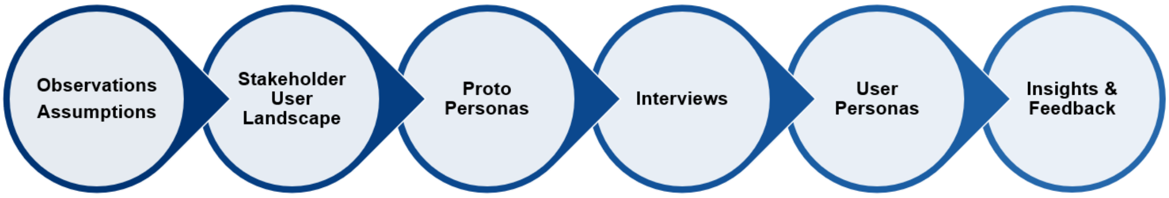

Figure 4. Research Strategy and workflow

This section outlines the approach and methods for gathering user data and information, as well as analysing the results. The general workflow strategy is as follows: First, from prior experience and market knowledge observations and assumptions were formed, from which stakeholder user landscape was created. Through brainstorming activities, users were categorized into different user categories based on their relevance and characteristics. From these groups, proto personas were created that describe a typical user from each category based on the initial assumptions and preliminary analysis. The proto-personas provided an understanding about the different user types, from students to seasoned professionals and researchers.

To gather a broad set of data points, structured survey was used to collect information on users' educational backgrounds, their familiarity with the concepts and experience with HPC and QC technologies, and their skillsets regarding the programming and software development. This data would provide a foundational understanding of the demographic and technical expertise landscape of quantum userbase at LRZ.

The next step was to consolidate and validate the proto personas with qualitative information, gathered through user interviews. During the interviews, the motivation, research objectives, pain points, frustration and expectations were explored. With information from multiple individuals within the same user category, we then developed comprehensive user personas. The final user personas were periodically refined and iterated, to validate the initial assumptions based on the real data from the interviews. These user personas document typical user types and their interactions with the system. To better understand user feedback and provides developers with a clear representation of the users they are designing services for.

This approach helped us ground the study in the real user needs and requirements which has and will continuously align the system development with the user needs. This study aims to collect actionable insights that could directly influence the design and development of the hybrid HPCQC systems at LRZ, ensuring the technologies QCT is developing are relevant, future-proof, and accessible to a diverse range of users in this community.
To achieve the objectives of the study the following activities have been designed and executed:

- Stakeholder mapping and market segmentation
- Developing a questionnaire to capture qualitative data
- Interactions and interviews with users to understand different use cases and user needs
- Derive functional and non-functional requirements
- Create personas representing different user groups
- Define epics and user stories
- Drive collaboration and understand the intersections of HPC and QC

B. Proto Personas

After the assumption phase and categorizing the user landscape, the next step has been to create proto personas. Proto personas are fictional characters based on assumptions and serve as a preliminary understanding of the types of users QCT would likely encounter. A template has been established to highlight common elements, which include:

- **Name**: A representative name for the user type.
- **Demographics**: Age, affiliated institute or company, and their position.
- **Short Biography**: A descriptive text about the user.
- **Research Objectives**: Potential research problems or categories and their goals.
- **Knowledge/Experience**: Skillset and previous experience.
- **Use Case**: An overview of the research problem.
- **Pain Points/Frustrations**: Potential barriers that hinder the research process.
- **User Needs/Requirements**: What they expect from the quantum ecosystem.

C. Data Collection Methods - Quantitative and Qualitative

This study involves a blend of both, quantitative and qualitative approaches. It is aimed at gaining deep insights into the needs and requirements, pain points and challenges, and the goals of the users in the High-Performance Computing and Quantum Computing space. By following this mixed method strategy, we intend to capture a broad-spectrum of data to gain deeper insights about user needs and requirements

Figure 5. Data collection strategy

Quantitative assessment – Survey

To capture quantitative information a structured questionnaire was developed to gather a broad set of data points from a large sample of users. The questionnaire consists of four sections, which aims to capture information on users' educational backgrounds, their familiarity with the concepts and experience with HPC and QC technologies, and their skillsets regarding the programming and software development. Further, it would provide a foundational understanding of the demographic and technical expertise landscape of the quantum userbase. The four sections are shown in the following image:
Further, the questionnaire was created with the survey tool from LRZ survey.lrz.de. The survey link or the QR code was included in the slides as part of QCT team activities during presentations

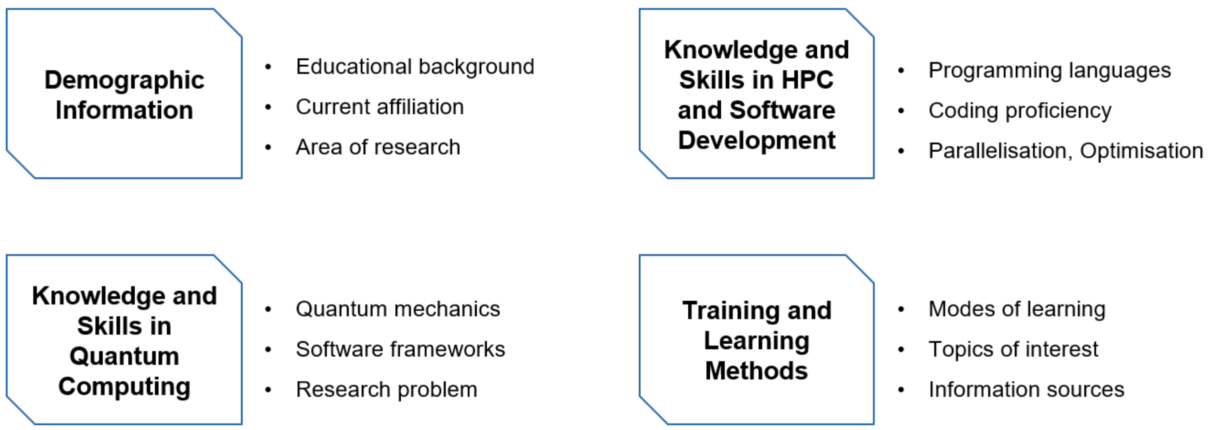

Figure 6. showing different sections and type of questions in the survey

at various events such as seminar, conferences, workshops to get responses.

Qualitative assessment - User Interviews

Qualitative methods, particularly in-depth interviews and user personas, complemented the quantitative data exploring the "why" behind the user behavior and user preferences.
User interviews allowed us to dive into how the users interacted with the quantum systems, what their current research objectives are, and the specific challenges they are encountering in realizing their goals; giving us a personal and subjective explanation to their behavior.
Users from different categories were approached to perform a one-on-one or small group discussion. The objectives of the study were explained to the participants and a verbal consent was obtained before starting the conversation. The participants were also explained about the data protection and confidentiality guidelines. The personal information of the participants would be maintained confidential and anonymous. A total number of 40 users (students, research assistant, research associates, research scientists) were interviewed from different user groups or categories. Based on the notes from the interview discussions, user personas were created.

D. User Workflows

Based on the identified user personas, specific workflows can be derived and highlighted. The diagram 7 represents a Unified Modeling Language (UML) flow of user interactions with the MQP. It begins with user authentication, which includes options for forgot password and request access if needed. Once authenticated, users are directed to a dashboard/status page, which serves as the central hub for accessing different functionalities. The system provides various features, categorized into different modules. The diagram highlights a well-structured user journey, emphasizing access control, monitoring, and interaction with resources.

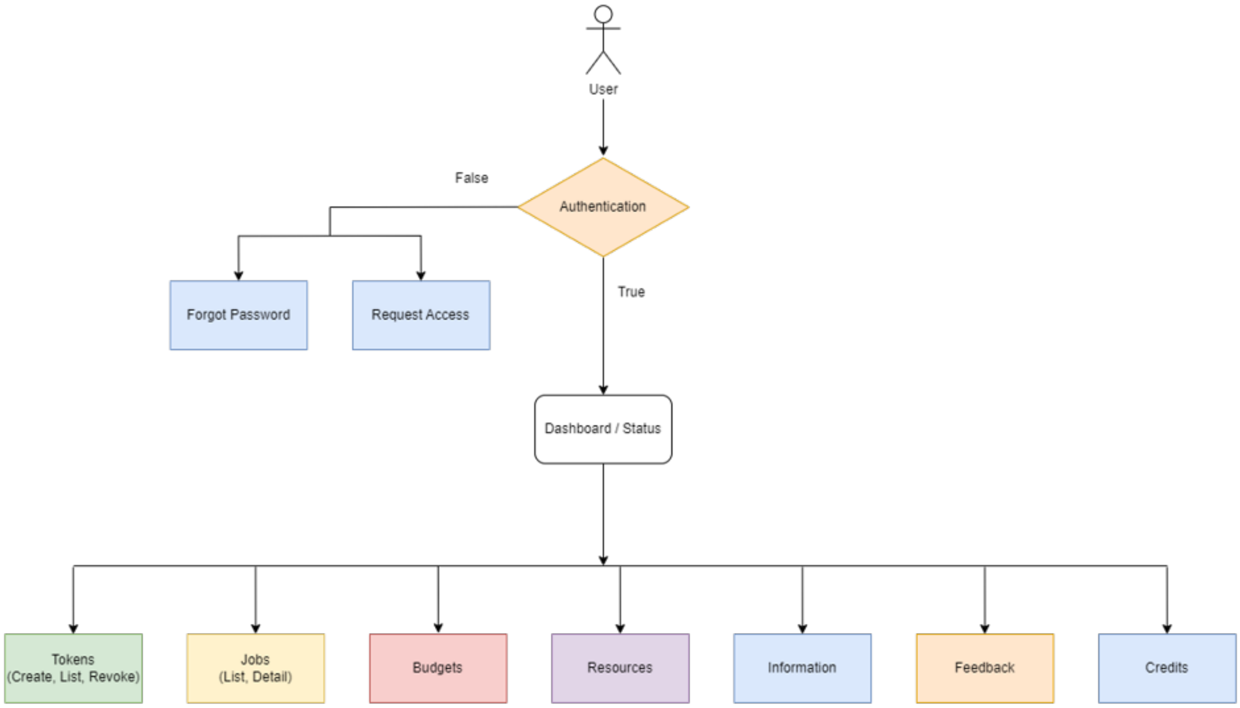

Figure 7. An activity diagram illustrating the step sequence and alternative flow of accessing the portal

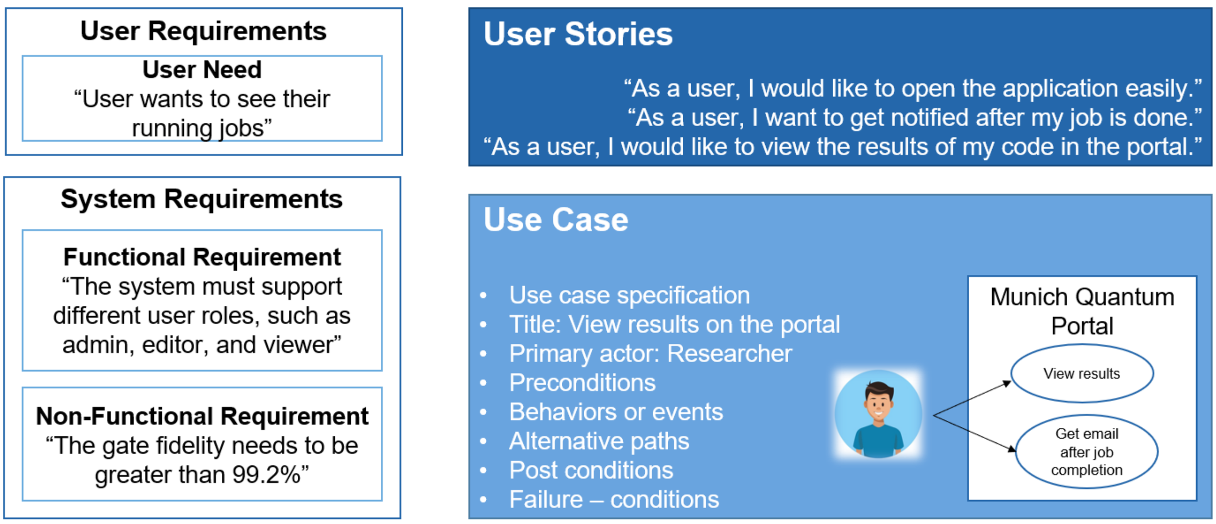

Figure 8. User requirements

The diagram 8 presents a structured overview of the user requirements, system requirements, user stories, and use cases for the Munich Quantum Portal, focusing on enabling users to monitor and retrieve their computational results efficiently. The user requirements highlight the core need for users to track their running jobs within the system. Expanding on this, the system requirements are divided into functional and non-functional aspects. Functionally, the system must support multiple user roles, including admins, editors, and viewers. On the non-functional side, a high gate fidelity of greater than 99.2% is essential to ensure the accuracy and reliability of quantum computations.
The **user stories** emphasize ease of use and automation, reflecting the need for users to quickly access the application, receive job completion notifications, and view their results within the portal. This aligns with the broader objective of creating a user-friendly and accessible quantum computing platform. It includes elements such as preconditions, expected behaviors, alternative paths, post-conditions, and failure conditions. Overall, the diagram underscores a user-centric approach to quantum computing, ensuring scalability, automation, and efficient access to results. The integration of role-based access control, notifications, and high-performance computing capabilities supports both technical and research-driven users in optimizing their workflow.
A generic workflow for a research scientist is as follows:

Workflow description: The research scientist wants to submit a job on the available quantum system on MQP **Steps**:

1. Open browser
2. Access the URL: https://portal.quantum.lrz.de/
3. Provide authentication details (Login)
4. Generate a token

5. Submit a job (Qiskit)
6. Check the status of job (Job pending/completed)
7. Once the job is completed, view the results
8. Results can also be downloaded
9. Token needs to be revoked after an interval

E. Munich Quantum Software Stack Management Tool

To ensure that user feedback from surveys, interviews, and Friendly User Pilot Phases (FUPPs) is systematically captured and acted upon, the Quantum Integration Software (QIS) team has developed the Munich Quantum Software Stack (MQSS) management tool. This is an internal tool which functions as an issue tracker enabling structured requirement handling for the software development team. For the end-users, there is the LRZ Service Desk which is used to manage incidents and service requests made by the users.

The workflow is as follows:

1. The User Enablement and Applications (UEA) team and solution architects create issue tickets in MQSS management tool for each identified user requirement or feature request.
2. The QIS team reviews these tickets, assigns priority categories, and groups them according to the priority classification.
3. Tickets are then assigned to the relevant development teams for implementation, with progress tracked directly in MQSS management tool.

By centralizing requirement tracking and prioritization in MQSS management tool, LRZ ensures that user needs are translated into actionable development tasks and integrated into the broader Munich Quantum Portal (MQP) roadmap in a consistent and transparent way.

IV. RESULTS

A. Pilot Study

The Quantum user study questionnaire as shown in Appendix VI was circulated among a group of Master's students during their visit to LRZ. A QR code was presented and the group of students were asked to submit their responses. The responses from the pilot study were analyzed to understand the group preferences and attributes.

Demographic Information: The study surveyed 25 Master's students from diverse educational backgrounds, including computer science, engineering, pure sciences, and business informatics. Most participants were beginners in quantum computing, with 72% having less than six months of experience and 28% having less than one year. Among the quantum software frameworks used, 68% of students worked with Qiskit, 32% with PennyLane, while 8% engaged with platforms such as Classiq, Intel QS, Cirq, MyQLM, Cuda-Q, and Q#. None reported using the Ocean SDK framework. In terms of programming proficiency, 84% were skilled in Python, 64% in C++, 48% in C, and 20% in other languages, including JavaScript, Shell Script, TypeScript, and MATLAB. Regarding their learning interests, 64% were eager to explore quantum principles and access different quantum hardware, 80% showed interest in high-performance computing (parallelization, MPI), and 40% expressed enthusiasm for cloud technologies and virtualization (VM, Docker).

Data highlights/observations:

- Quantum Computing Experience: The majority of students were beginners, with most having less than six months of exposure.
- Quantum Software Usage: Qiskit was the most widely used framework, while PennyLane had notable adoption. Other frameworks saw minimal engagement, and none used Ocean SDK.
- Programming Skills: Python was the most common language, followed by C++ and C, with a small percentage proficient in other languages.
- Learning Interests: A significant portion expressed interest in different quantum technologies, having hardware access and high-performance computing, AI and machine learning.

The bar chart in Figure 11, highlights the primary interest of students related to various topics

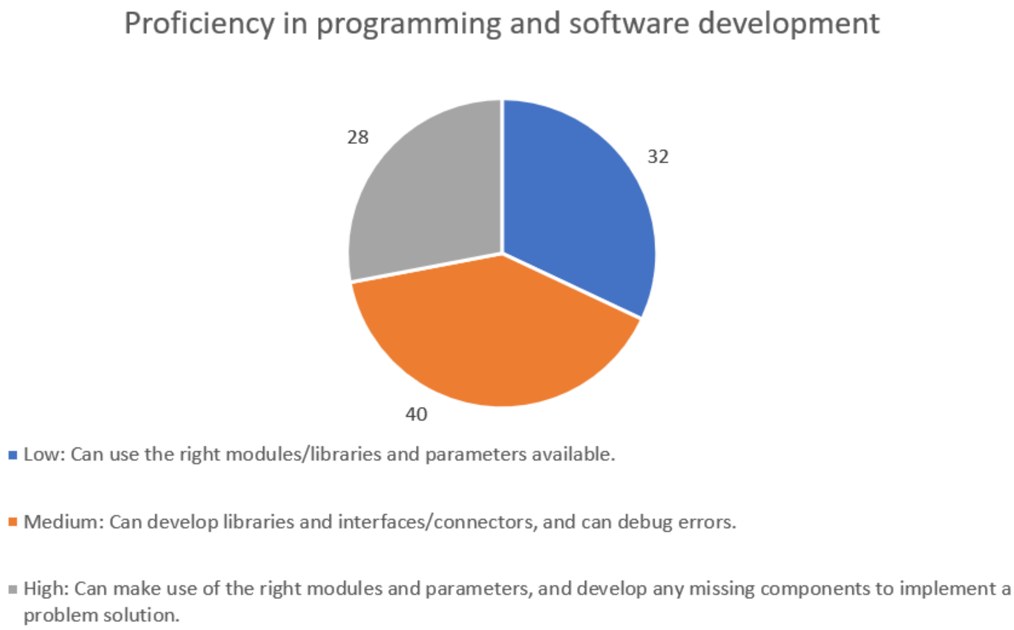

Figure 9. Percentage of students expressing their proficiency in different programming languages

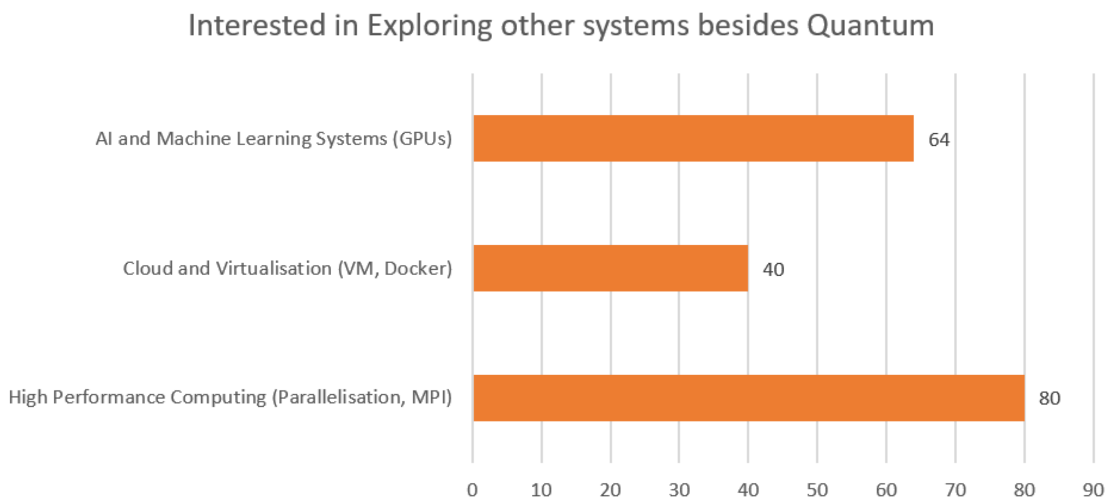

Figure 10. Percentage of students expressing their Interest in different systems besides quantum

in quantum computing. The primary interest of students were in topics such as optimization (56%), followed by error correction, quantum algorithms, quantum computing topics in general and quantum machine learning (48%), which are critical for advancing quantum computing applications. Around 44% students expressed their interest in hybrid classical and quantum computing, reflecting on the importance of integrating quantum with classical. Noise and hardware related topics were of less interest, possibly due to their complexity in understanding the

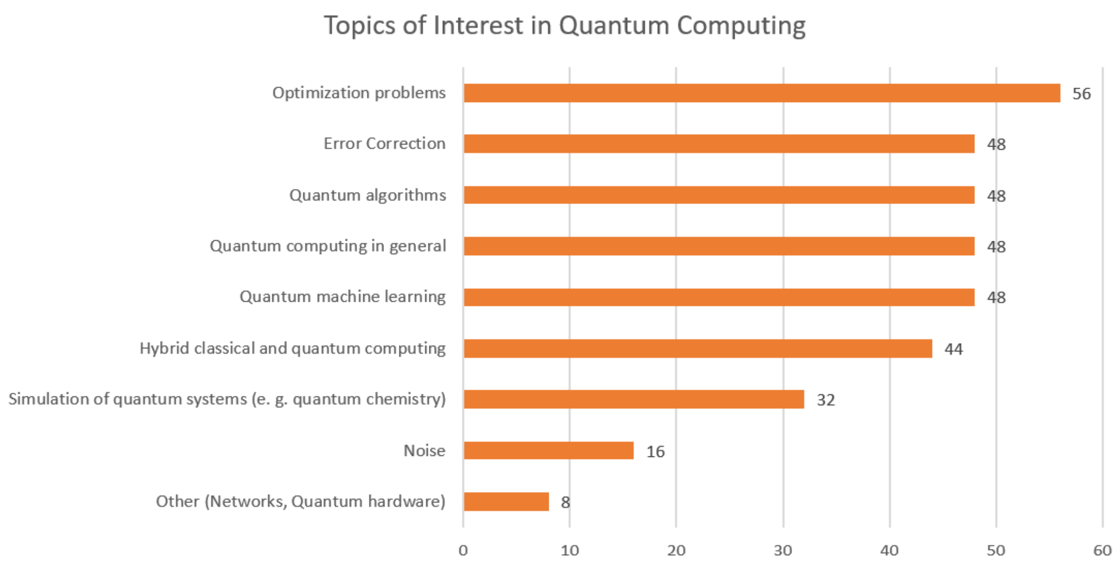

Figure 11. Percentage of students expressing their Interest in different topics related to quantum computing

topics.

B. User Groups and Categories

This part highlights the identified user groups from the engagement with users. We have determined the following user groups:

Senior Research Scientist/Program Manager:

- Profile: PhD, 10+years of research and professional experience
- Motivation: solve complex problems, industry applications, drive scientific curiosity
- Interaction/engagement: research, project management, managing different research groups

Research Scientist/Research Associate:

- Profile: Master's degree or PhD
- Motivation: research
- Interaction/engagement: research and collaboration, contributions to the scientific publication

Computer Scientist:

- Profile: 5+ years of experience

- Motivation: HPC-QC Integration, workflow development
- Interaction/engagement: software development programming, contribute to software libraries, participation in hackathons

Users from Industry:

- Profile: diverse educational background
- Motivation: looking for business optimization using Quantum computing
- Interaction/engagement: looking for collaboration, research and consulting

Students:

- Profile: enrolled in Master's program
- Motivation: learning new things, curiosity, career prospects
- Interaction/engagement: internships, interested in trainings/workshops, need mentoring and guidance

Users from Startups/Entrepreneurs:

- Profile: Master's degree, interested in entrepreneurship related prospects
- Motivation: exploring different use case application
- Interaction/engagement: pitching ideas and looking for investors, exploring funding opportunities/grants, collaborations and consulting

Users from Academic or Research Institutions:

- Profile: professors, research Program Managers
- Motivation: academic collaboration & consulting
- Interaction/engagement: looking for collaboration, research & consulting, partnerships

Funding Agencies:

- Profile: research background with public service Interests, administration, project management
- Motivation: to drive innovation and research in QC
- Interaction/engagement: grant allocation, project evaluation, publications

Common observations across different user groups

Cloud services - preferences:

- Most stakeholders prefer cloud-based quantum and HPC platforms for scalability, access to remote resources, and cost efficiency.
- Students: rely on free cloud quantum platforms

- Research Scientists: need cloud integration support (Hybrid HPC + Quantum)

Software framework usage:

- Qiskit is the most commonly used framework, followed by PennyLane, Cirq, and TensorFlow Quantum.
- PennyLane is well suited for variational algorithms
- Data Scientist and AI/ML experts prefer TensorFlow Quantum for integrating quantum with AI

Training and educational needs:

- Students: require proper training and courses from beginner to advanced levels Researchers and developers: focus on applications and optimization
- Students: participation in Hackathon for experience

Industry Use Cases:

- Active exploration of different applications

Mentoring and Consultation:

- Students require academic mentoring and guidance for their thesis work
- Industries, Businesses and StartUps: explore different quantum applications and seek consulting support

Despite differences in focus areas, all stakeholder groups share a strong need for cloud access, Qiskit-based frameworks, educational resources, and expert mentorship. While technical users (researchers, developers, IT administrators) focus on optimization and scalability, business users prioritize industry-specific applications and return on investment.

A user-centered approach to quantum and HPC development should accommodate both deep technical users and non-technical stakeholders, ensuring accessibility, usability, and business viability.

C. User Personas

User Experience designers have a responsibility to make sure that the service they are responsible for (eg. a website or an app) is easy to understand, use and navigate. User Personas are one way of understanding users, their needs and preferences and designing elements that match the user requirements. A persona is a description of a hypothetical, generic person who represents a user group with similar characteristics and needs. Personas are used to understand the user requirements and design according to the user needs. An actionable customer insights are gathered through personas for designers or software development team. The persona template used in the QUS is shown in figure 12.

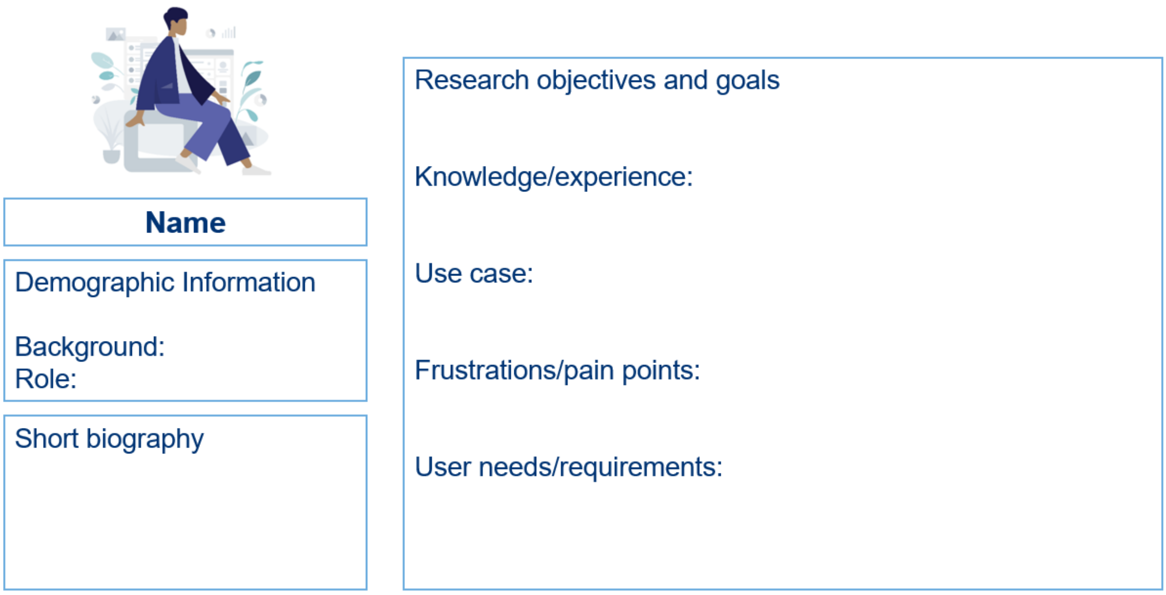

Figure 12. User persona template

User personas are fictional representation of ideal users to target users. They are created to:

- Represent the various user groups interacting with the portal
- Capture their specific needs, behaviors, and goals
- Focus on their characteristics, attitudes and challenges
- Examine the user expectations
- Build better products that serve a purpose or solve a problem for the users
- Create a product that considers different types of users
- Prioritize on what is critical and what is not
- Align assumptions to work together efficiently

Figure 13 presents examples of various user personas, each representing a distinct type of user with specific characteristics, needs, and behaviors. These personas typically include details such as demographics, goals, experience/skill set, pain points, and potential interactions with a product or service. This structured approach helps in documenting typical user types and understanding how they interact with the system, ultimately guiding the design and development of services. Personas enable a user-centric approach to the design, adoption, and optimization

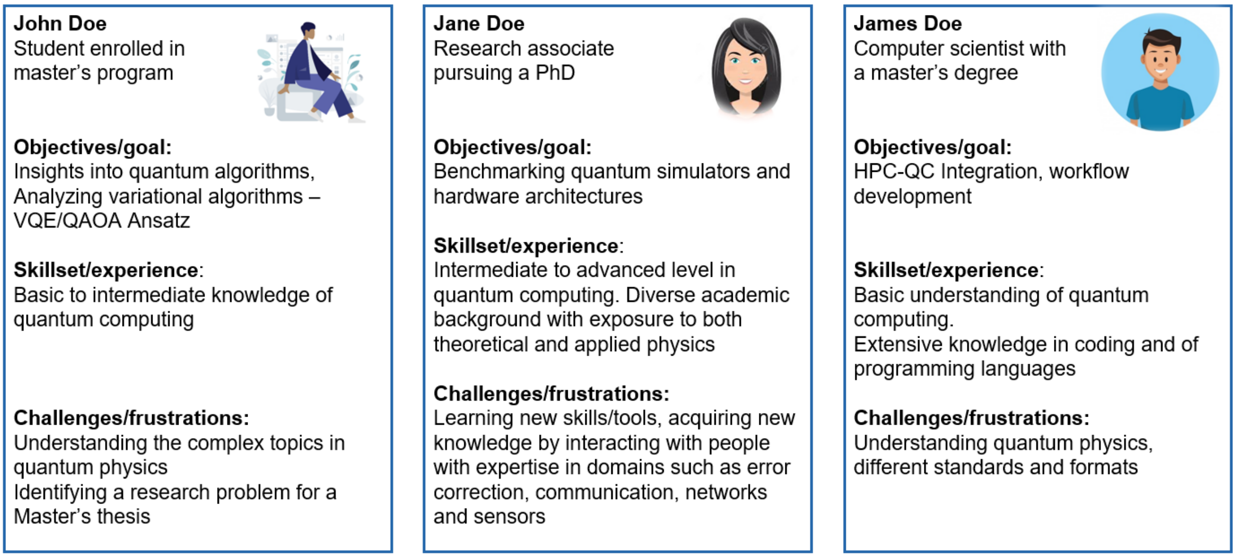

Figure 13. User Persona Examples

of QC and HPC technologies. By understanding the unique needs of different stakeholders, organizations can develop better interfaces, enhance accessibility, and maximize the impact of advanced computing systems across various domains.

D. User Requirements – specification and actual requirements as results

This section summarizes the results from the survey and interview discussions. The qualitative data from the interviews were analyzed and the following user requirement classes have been identified:
The mentioned requirements can be grouped into five general classes.

Access: this topic is high on the list for many users, who only have access to simulators so far and are interested in using quantum hardware. There are important features which need to be assessed and implemented around the administrative and usability aspect of access.
Quantum Hardware: These are the requirements, that users have to be hardware itself.Be it fidelity, a certain topology or other qualitative aspects.
Support: support is an overarching aspect of providing quantum services. These are requirements, that users need in terms of consultancy and assistance that they can execute their workflows.

System Software: in system software covers the features, that users have for the functionality and compatibility of the system.
User Interface: user interface plays an important role in the usability and ease of use with the system. In this class, the requirement that users have to the front-end are highlighted.

This table highlights some of the requirements gathered from the data.

Code	**Feature**	**Requirement Name**	**Description**	**Priority**	**Acceptance Criteria**
FR-A-1	Access-Quantum Hardware	Access to quantum hardware	User of all skill levels, from novices to experts, are requesting access to quantum hardware for their research. Relying solely on quantum software simulators is restricting their potential.	Must	Users are able to use quantum hardware
FR-A-2	Access- Unified Platform	Unified access to different quantum systems	Users seek a unified access point to multiple systems to ensure consistency, avoid fragmented formats and settings, and eliminate the need to learn varying system characteristics	Should	Several quantum devices are connected and accessible.

Code	**Feature**	**Requirement Name**	**Description**	**Priority**	**Acceptance Criteria**

FR-H-1	Modern quantum systems	Modern quantum systems	Users want access to the latest quantum systems with cutting-edge features, including a qubit count that reflects current technological advancement	Should	The quantum hardware is up-to-date and incorporates the latest technological developments
FR-H-2	Hardware-Stability	Sytem availability	Users are looking for stable quantum systems that are available and free from unplanned downtime.	Must	The quantum systems are operational and have the uptime as promised.

Code	**Feature**	**Requirement Name**	**Description**	**Priority**	**Acceptance Criteria**
FR-SP-1	Support Consulting	Consulting team	Users look for help and guidance from quantum experts and specialists when they face new questions or problems.	Should	A support team is available to be contacted for issues.
FR-SP-2	Support-User Documentation	Documentation and instructions to use the quantum services.	Users are looking for well-structured documentation to reference for instructions and common workflows. It needs to be clear, precise, and easy to navigate.	Should	Users can utilize the quantum services independently, guided solely by documentation, without needing personal assistance.

FR-SP-3	Support-Technical Specification	Information about the architecture and characteristics of the quantum system	Users want to know the technical specifications and deeper insights of the quantum systems.	Should	Documentation of the technical system specification are made available.
FR-SP-4	Support- System Software Documentation	Documentation of the system software architecture	Users want to understand the system architecture and processes, such as what happens in the background when a circuit is submitted and how jobs are scheduled.	Could	Users understand the design of the software system architecture.

Code	**Feature**	**Requirement Name**	**Description**	**Priority**	**Acceptance Criteria**
FR-SS-1	System Software- Hybrid Classical Quantum Integration	Hybrid Classical Computing	Users express their interest to run hybrid quantum classical tasks on the system.	Must	User can use quantum service for hybrid quantum classical computing tasks.
FR-SS-2	System Software-Advanced Control	Advanced access to the quantum systems	Users want more control over parameters and access to additional information from the quantum systems.	Could	Users gain access to addtional system parameters.

FR-SS-3	System Software-Standard Formats	QASM as standard circuit format	Users prefer a standardized circuit format, such as QASM, to enhance ease of use and interoperability with the system.	Could	QASM is used as a standard circuit format.
FR-SS-4	System Software-Job Profiling	Job and system profiling	Users seek more detailed insights into their jobs and the system during execution, including metrics such as latencies, fidelity, and system noise.	Could	Users get more system information about their jobs.
FR-SS-5	System Software-Bare Hardware Access	Direct access to quantum hardware	Users express a strong interest in gaining more direct access to quantum hardware and working as closely as possible with the system.	Could	Users get access to the system through a low level interface.
FR-SS-6	System Software-Calibration Data	Access to system calibration data	Users want access to system calibration data to better analyze system performance and interpret their results.	Should	Users can download the system calibration data.
FR-SS-7	System Software-Coupling Map Data	Access to system coupling map	Users want insight into how their circuit is compiled and executed on the QPU, including the qubit connectivity.	Should	Users can download the coupling map.

FR-SS-8	System Software-Timing And Latencies	Circuit transpilation time	Users seek insight into the transpilation process, including its duration, optimization steps, circuit depth, and overall execution time.	Should	Users can download the time measurement information of different process steps.

Code	**Feature**	**Requirement Name**	**Description**	**Priority**	**Acceptance Criteria**
FR-UI-1	User Interface-Accessibility	Basic user interfaces	Users are interested in having a simple interface with automation tools to streamline the execution of routine tasks.	Could	There is a basic user interface alongside expert settings.
FR-UI-2	User Interface-Job Overview	Overview and list of user jobs	Users want to stay informed about the status of their running, completed, or failed quantum jobs.	Should	Users can see their active and inactive jobs.
FR-UI-3	User Interface-Hardware Parameter Readout	Insight of hardware parameters	Users want to see the status and parameters such as gate timings in the user interface.	Could	Users can see the hardware characteristics.

Common observations and insights

- Users across different categories require direct access to quantum hardware, as relying on simulators limits their potential. A unified platform integrating multiple quantum systems is preferred to streamline interactions and reduce complexity.
- Users seek the latest quantum hardware with cutting-edge features and stable availability, minimizing unexpected downtimes.

- Comprehensive documentation, consulting services, and system specifications are crucial for users to independently navigate and troubleshoot quantum systems.
- Users request hybrid classical-quantum computing, enhanced control over system parameters, job profiling, access to calibration and coupling map data, and insights into execution metrics such as latency and noise.
- A user-friendly interface with job monitoring, hardware parameter insights, and automation tools is desired to improve accessibility and usability.

E. Challenges or Pain Points

Based on the interview discussions, the following list of challenges were identified:

1. Hardware access

   Academic researchers and startups have restricted access to quantum hardware due to costs, queing times and qubit counts. There are limited resources and different quantum technologies have limited qubit counts and the results are influenced by noise and errors. Due to the high costs, most end users do not have access to hardware and are limited to software simulators.
2. Unavailability of implementation (Published papers/articles mention about different methods, but not all can be easily reproduced or implementable)

   Academic papers and published articles propose different novel methods, algorithms and techniques omitting information on practical implementation. They would not share the code, ignore the noise and decoherence making it a challenge for researchers and users to reproduce or test the method/techniques. Researchers would have to dedicate significant time to reverse engineer algorithms.
3. Code implementation in different languages

   Researchers use different quantum programming languages and frameworks with unique syntax and quirks, translating code between different languages is complex and prone to errors. The absence of standardized APIs across platforms makes it a challenge for researchers for benchmark comparisons and seamless algorithm development and testing.
4. Benchmarking – Comparison with different methods and publishing the results

   Comparison of different methods, algorithms or systems requires robust benchmarking metric which becomes a challenge due to noise and hardware imperfections. Further, scalability becomes a challenge with increasing qubit numbers and job size.

5. Learning about different systems

   The quantum landscape includes diverse architectures (superconducting, neutral atoms, trapped ions, photonics) with unique properties, strengths and limitations. There is a need for educational resources to educate and help users about different architectures and adapt algorithms to different systems.

6. Scaling of Quantum computers – in the context of qubit numbers

   As the number of qubits increase, the system tends to become susceptible for errors, reducing reliability of results. Often users experience the challenges of noise, decoherence, system constraints such as availability of gates, cryogenic requirements and resource trade-off painpoints when it comes to achieving quantum advantage.

7. Massive Parallel variations - exploring classical parallelization using traditional technology

   Drawing parallels between classical parallelization techniques and quantum computing is non-trivial due to fundamental differences in computing models. To adapt classical parallelization strategies to quantum simulation often requires significant rethinking of establishes methodologies. It is also resource-intensive. While classical paraell computing has mature tools such as MPI, Open MP, CUDA, equivalent quantum simulation tools are still underdeveloped.

8. Error correction and noise mitigation

   Quantum systems are inherently error-prone due to noise, decoherence, and imperfect gate operations. Implementing effective quantum error correction (QEC) is critical but resource-intensive. Understanding and mitigating errors requires detailed modeling of hardware-specific noise, which varies across architectures. Further, the qubits lose their quantum state over time, making long computations unreliable and challenging.

9. Heuristic uncertainty

   Many proposed algorithms are heuristic, meaning they lack rigorous guarantees of performance improvements over classical approaches. Success of heuristic algorithms is often dependent on the specific problem and data set. The users cannot predict whether a heuristic algorithm will outperform classical methods for their specific use case. Users also must rely on trial and error experimentation to determine the validity of a heuristics algorithm, making it an iterative and time-consuming process. These algorithms also lack robust and standard benchmarks for comparison. Scenario: VQE is widely used for finding the ground state energy of molecules. It is heuristic and its performance depends heavily on the choice of ansatz and the optimizer, which require domain specific expertise and extensive experimentation. With the various software frameworks, there are also different data formats which are not standardized and interchangeable. Consequently, there is the need for conversion tools now.

10. Quantum-to-classical integration: Complex workflows and optimization challenges
    Most quantum algorithms require hybrid quantum-classical workflows, but integrating quantum systems with classical infrastructure is non-trivial. Orchestrating quantum and classical computations require advanced software frameworks that are still evolving. Efficiently distributing workloads between quantum and classical components is an open research area.
11. Business and Economic feasibility
    Quantum research and hardware development requires significant funding and most use cases (cryptography, optimization, material simulation) are far from maturity. This makes it a challenging business to justify investments.
12. Ethical and Security concerns
    The advancement in quantum computing has significant ethical and security risks specially in cryptography and data privacy. Privacy and sensitive data are a concern but that is similar to classical computing. As most users are currently in research groups, there are no real end users who just want results as the outcome. There is a need for proper laws, guidelines and standard protocols to address any vulnerabilities, accessibility concerns and unethical practices.
    Overcoming these barriers requires collaboration between different academic, industry and government institutions to improve hardware access, standardize tools and understand different use cases to achieve quantum advantage.

V. FRIENDLY USER PILOT PHASE

The Friendly User Pilot Phase (FUPP) is a stress-testing period designed to evaluate new quantum hardware and its access using Munich Quantum Portal (MQP) before opening access to the

broader user community. For the Q-Exa system, the FUPP ran from July to the end of October, and for the AQT system, the FUPP ran from March until the end of May. A small group of selected pilot users was invited to each Friendly User Pilot Phase, based on criteria such as alignment with Munich Quantum Valley (MQV) priorities and relevance of their use cases. Each user team was assigned two Quantum Computing and Technologies (QCT) solution architects as primary points of contact. Communication channels included a dedicated Element chat for rapid issue reporting, open mic Zoom sessions for deeper technical discussions every week, and a dedicated mailing list for updates such as downtime notices. This setup enabled close collaboration between users, the IQM and AQT teams, and QCT consultants, fostering quick feedback loops and targeted improvements to both the hardware operation and MQP.
Participants in the pilot testing of the Q-Exa and AQT quantum systems provided detailed feedback on usability, performance, and feature availability. The following summarizes common themes along with representative user comments. The feedback presented here was collected during the Friendly User Pilot Phase through surveys and final reports. Quotes are presented anonymously and reflect the users' own words, lightly edited for readability where necessary.

A. System Stability and Availability

- *"The quantum hardware has been slightly unstable, being offline for maintenance sporadically, and there was a period where only 19 qubits were available."* [Fixed]
- *"Not having access to parts of the IQM control stack restricted the amount of compilation optimisation and error suppression we could achieve."*

B. Portal Integration and Debugging

- *"Easy access to the system via API key, and seamless integration into the Qiskit Backend paradigm."*
- *"It was overall hard to debug with the error messages that we got."*
- *"It wasn't always clear which system was usable or not — systems would appear Online on the MQP dashboard but jobs couldn't be sent to the backend."* [Fixed]

C. Job Execution and Output Handling

- *"Trivial circuits executed smoothly. More complex circuits (e.g., from the reproduction package) presented technical issues that were eventually resolved."*
- *"It became difficult to access detailed information about individual jobs via the MQP portal. This was mitigated by limiting the output to 200 jobs, but a more sustainable solution (e.g., paging) is needed."* [Implemented]
- *"Some metadata was encoded as Python code inside JSON values, which poses portability issues for users relying on other software stacks."*
- *"The .csv output format was hard to parse — it would be much simpler if information were available as a JSON file that loads as a Python dictionary."* [Implemented]
- *"There is no known method to download results automatically — having to download each job result manually was a major obstacle."* [In Progress]

D. AQT System Performance and Queueing

- *"The overall usage of the AQT system over the MQP platform went very smoothly and intuitively."*
- *"The dashboards were helpful for checking job status, execution times, and accessing results."*
- *"At the beginning, queue times were too long for fast-running experiments. The introduction of batch splitting significantly improved the situation."*
- *"For future projects, it would be helpful to schedule closed queue times or increase the shot count beyond 200."*
- *"We experienced great support from the LRZ team..."*

E. Feature Requests and Future Improvements

- *"A tag system in the portal to group jobs belonging to the same script would be very useful."* [Planned]

- *"It should be possible to cancel multiple jobs from the job page."* [In Progress]
- *"Information on current system usage (e.g., number of active users) would help with planning."* [Planned]
- *"Quantum hardware must support higher gate counts or allow low-noise execution of deeper circuits."*
- *"Error mitigation tools such as readout correction and basis translation would be beneficial."*
- *"We initially planned to run analog quantum simulations on AQT, but pulse-level access wasn't available. For the future, it would be desirable to support limited access at this level."* [Implemented for Q-Exa]

Since the Q-Exa pilot phase preceded the AQT Friendly User Pilot Phase, several user-raised issues had already been addressed by the time AQT testing began. For instance, instead of relying solely on a general queue, the AQT FUPP introduced a system of designated usage slots allocated to each participating user team. While all users could still submit jobs at any time, jobs submitted within a team's assigned slot were prioritized. If the designated team was not actively using the system during their slot, unused capacity was automatically reallocated to others in the general queue. Remaining user requirements continue to be tracked in the Quantum Integration Software team's development backlog for future implementation.

VI. OUTLOOK

As a continuation of the Quantum User Study (QUS), LRZ is actively working on the implementation of prioritized requirements gathered from the Q-Exa and AQT Friendly User Pilot Phases (FUPPs). Insights from these pilots are being integrated into the design and feature roadmap of the Munich Quantum Portal (MQP), as well as into consulting services and research collaborations.

A key next step is the structured documentation of domain-specific use cases. This will not only guide technical improvements but also inform the development of targeted education and training programs, based on the knowledge and skills identified in the survey data.

Requirements Management Process:

- **Collecting feedback and use case documentation:** Capture insights from FUPPs, develop user guides, and record domain-specific requirements.
- **Requirements identification and enhancement:** Translate feedback into technical improvements, UX enhancements, and new feature proposals.
- **Prioritization and categorization:** Group requirements into different priority categories for effective planning and resource allocation.
- **Use case analysis and implementation:** Analyze documented use cases and implement the most impactful requirements.

Looking ahead, LRZ plans to launch additional Friendly User Pilot Phases as new quantum hardware becomes available. These phases will continue to serve as both usability stress tests and feedback mechanisms, ensuring that services remain aligned with real user expectations.

The transition toward a regular user operations model is also underway. This includes defining access policies, usage parameters, and sustained support strategies—ensuring that quantum services can evolve from experimental pilots into scalable, production-ready infrastructure accessible to the broader academic and research community.

By recognizing shared needs and tailoring requirements, LRZ can strengthen the integration of quantum and HPC resources, supporting diverse stakeholders and driving continuous innovation.

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APPENDIX A: QUESTIONNAIRE

General Background

What is your highest diploma or current level of education?

1. High school diploma
2. Associate's degree
3. Bachelor's degree
4. Master's degree
5. Doctoral degree
6. Other:

In what field of study did you get your latest degree?

What is your current primary field of work, research or area of expertise?

1. IT, computer science, software engineering
2. Applied sciences, engineering, medicine
3. Physics, mathematics, chemistry
4. Business administration, management
5. Other

What is your occupation?

How many years of experience do you have?

1. 0 - 6 months
2. 6 months - 1 year
3. 1 - 3 years
4. 3 - 5 years
5. 5 years and above

Knowledge and Skills of Quantum Computing

What topics in quantum computing interest you?

1. Quantum computing in general
2. Quantum machine learning
3. Optimization problems
4. Simulation of quantum systems (e. g. quantum chemistry)
5. Quantum algorithms
6. Noise

7. Error correction
8. Hybrid classical and quantum computing
9. Other:

Which concepts in quantum mechanics and quantum computing do you understand well?

1. Wave, phase, amplitude
2. Schrödinger's equation
3. Qubits, Bloch sphere
4. Superposition, entanglement
5. Energy states
6. Noise
7. Decoherence times
8. Gates
9. Circuit construction
10. Quantum Ansatz
11. Quantum algorithms
12. Error correction

How would you describe your experience level with quantum computing?

1. Novice: Limited or no prior exposure
2. Beginner: Some basic understanding but limited hands-on experience
3. Intermediate: Moderate experience with practical application
4. Advanced: In-depth knowledge and hands-on experience
5. Expert: Extensive experience, possibly involved in research or development

Of which type(s) of qubit technologies do you know the principles and can explain their technical operation?

1. Superconducting
2. Trapped Ion
3. Neutral Atoms
4. Photons
5. Topological qubits
6. Quantum dots
7. None
8. Other:

Which of these quantum algorithms you understand well?

1. Deutsch–Jozsa algorithm
2. Quantum phase estimation algorithm
3. Shor's algorithm
4. Grover's algorithm
5. QAOA
6. VQE
7. None
8. Other:

What quantum systems have you worked with so far?

1. Quantum software simulators (e.g. Qiskit Aer, Intel QS, PennyLane, Cirq, cuQuantum)
2. Quantum hardware simulators (e.g. Eviden Qaptiva/Atos QLM)
3. Quantum hardware (e.g. IBM, Google, Rigetti)
4. Quantum annealers (e.g. D-Wave, Fujitsu)
5. Other:

What quantum software frameworks are you currently using?

1. Qiskit
2. PennyLane
3. Cirq
4. Q#
5. Intel QS
6. Ocean SDK
7. Other:

What is the highest number of physical qubits you have worked with so far?

What is the highest number of simulated qubits you have worked with so far?

What is the distribution of classical and quantum computing tasks in the problems you work on?

1. classical
2. more classical
3. hybrid 50/50
4. more quantum
5. quantum

What problems in quantum computing are you currently researching or trying to solve?

Knowledge and Skills of HPC and Computer Science

What programming languages are you proficient in past the basics?

1. Python
2. C++
3. C
4. Java
5. Fortran
6. Rust
7. Other:

What is your main editor or environment you use for software development?

1. Browser (e.g. Jupyter Notebooks, AWS Cloud9)
2. IDE (e.g. Visual Studio Code, PyCharm, Eclipse)
3. Shell (e.g. vim)
4. Other:

Which technology topics do you have a fundamental understanding in?

1. DevOps
2. Microservices, API
3. Virtualization, containers, IT automation
4. Cloud computing, cloud applications
5. IT security, encryption
6. 5G, IoT, edge computing
7. Big data, data storage, data services
8. Other:

Which concepts in programming do you understand well?

1. Data structures and algorithms
2. Database and SQL
3. Development frameworks
4. Web development
5. Integrated development environment (IDE)
6. Object-oriented programming
7. Testing, debugging

8. Cloud computing, Containers
9. Networking
10. Version control
11. Other:

Where would you place your proficiency in programming and software development?

1. Low: Can use the right modules/libraries and parameters available.
2. Medium: Can develop libraries and interfaces/connectors, and can debug errors.
3. High: Can make use of the right modules and parameters, and develop any missing components to implement a problem solution.

Training and Education

What is your preferred way to approach new topics?

1. Lectures, talks
2. Online courses, webinars, videos
3. Training, workshops, seminars
4. Journal articles, research papers
5. Books
6. Conversations
7. Other:

How would you prefer a training course content to be organized?

1. presentations only
2. more presentations
3. good mix of lecture and exercises
4. more exercises
5. hands-on exercises only

How do you prefer to learn new content?

1. theory-oriented
2. more theory
3. good mix of theory and application
4. more application
5. application-oriented