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Quantum Computing Circle – A Descriptive Case Study on Teaching Quantum Computing in a Business School

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ABSTRACT

Quantum computing holds immense disruptive potential impacting technology, business, and society. Despite its significance, its complexity poses accessibility challenges. Consequently, diverse teaching approaches are being explored by educational institutions. While tech-savvy audiences are addressed, offerings for business-oriented individuals are scarce. In 2023, the authors of this publication secured funding for the 'Quantum Computing Circle', an educational initiative aimed at familiarizing business managers/students with quantum computing. This program, comprising twelve teaching hours including hybrid lectures and lab exercises, supplemented with self-study and an online test, was piloted with a cohort of approximately 50 bachelor-level students across two universities in spring 2024. This paper delineates the course's design, implementation, and outcomes, including student and lecturer feedback as well as learning achievements. It provides didactic recommendations and insights for educators in emerging technologies like quantum computing, serving as a starting point for further research in quantum computing education.

Keywords: Quantum computing, Business audience, Hybrid education, Higher education

INTRODUCTION

Quantum computing (QC) leverages quantum mechanics to perform computations beyond the capabilities of classical computers. Using qubits, QC promises to solve dedicated complex problems more efficiently (e.g., computationally or thermodynamically) compared to classical computers, and it has the potential to disrupt industrial sectors such as finance, healthcare, and logistics (Kar et al., 2025). The economic impact of QC on the leading industries is projected to reach $1.3 trillion by 2035, particularly benefiting financial services and life sciences (Bogobowicz et al., 2023). Public and private sectors are investing heavily in QC. Globally, the U.S., China, and the European Union are leading public investments. In the private sector, large tech corporations like Google, Microsoft, IBM, and Intel are pioneering QC advancements (MarketsandMarkets, 2024; Bogobowicz et al., 2023). Many companies have launched initial innovation projects in order to capitalize on these technologies, rather than risk being left behind. However, a major problem long known is talent shortage (Goubet, 2018). Politicians have recognized this rising pressure and have instituted various programs. For instance, the Federal Ministry of Education and Research in Germany (BMBF) has initiated a quantum systems research program with the aim to make Germany a world leader in quantum computing (BMBF, 2022). In Switzerland, for example, the Swiss Quantum Initiative (SQI) aims to strengthen the leading position of the country in the quantum realm. For 2023/24, the new initiative was allocated CHF 20 million for leading research, technology transfer, curricula development or international partnerships in addition to the existing funding (*Swiss Quantum Initiative (SQI)*, 2025).

Overview of State of Quantum Computing Education

The different approaches to integrating quantum technologies into school and university curricula between 2001 and 2021 are summarized in a comprehensive review article by (Bitzenbauer, 2021). However, efforts were mainly concentrated on bachelor, master, or PhD degree programs in the natural sciences (especially physics) and computer science. Until now, the subject of quantum technology has hardly been taught outside these areas (Ebai et al., 2024). Nevertheless, there are online materials on QC offered by organizations such as IBM (IBM, 2016), CERN (Fernandez-Combarro Alvarez, 2020), LinkedIn Learning (LinkedIn Learning, 2019), and Udemy (Nelson, 2025). The limited number of graduates in the QC-field worldwide is offset by a growing demand for workers in the various areas of quantum technology (Fox, Zwickl and Lewandowski, 2020). Companies therefore need to develop in-house expertise by investing in education and strengthening their collaboration with universities and research institutions (Ramesh and Sarkar, 2025). Private and public collaboration initiatives such as IBM's Quantum Data Center (Crowder and Thoß, 2024), the Quantum Center at ETH Zurich (*ETH*, 2025), or the Quantum Circle in Belgium (Morissens, 2025) are platforms fostering teaching and research in QC. Besides the limited number of graduates in the QC-field, other challenges plaguing QC education include limited available solid knowledge and cases, given that the technology is still undergoing development (Carberry et al., 2021), inadequate academic knowledge to teach, and the challenge of promoting accessibility to individuals with diverse educational backgrounds (Al-Juboori and Noonan, 2024).

To address the challenge of skill shortage and define the diverse technical, non-technical, and less technical requirement profiles for a "quantum workforce", the European Competence Framework for Quantum Technologies has been developed and refined (Greinert et al., 2023). This framework, in its latest version 3.0, is based on the European Qualification Framework (European Commission et al., 2025). It focuses on knowledge and skills at various proficiency levels. It primarily addresses advanced training in relevant industrial environments, with proficiency levels ranging from A1 to C2, corresponding to A1 Awareness, A2 Literacy, B1 Utilisation, B2 Investigation, C1 Specialisation and C2 Innovation. The schematic allows for the visualization of proficiency levels across nine qualification profiles (QT- 1. aware person, 2. informed decision maker, 3. literate person, 4. practitioner, 5. business analyst, 6. engineering professional, 7. specialist, 8. strategist, and 9. core innovator). These profiles describe the competences and requirements for involvement in the quantum industry. A link between the competence frameworks and concrete job profiles (which also include non-technical roles) was established by Greinert et al. (2025).

Relevance of Quantum Computing for Business Students

Recognizing the profound impact QC is poised to have on various industrial sectors, it is crucial to expand educational outreach to include (future) decision-makers in businesses. A diverse workforce skilled in quantum technologies will be essential to exploit QC and advance economy and society (Mohr et al., 2022). Studies in Europe and the U.S. have highlighted the growing need for non-technical professionals to understand QC basics to work alongside technical experts (Greinert et al., 2023; Kaur and Venegas-Gomez, 2022; Fox, Zwickl and Lewandowski, 2020; Venegas-Gomez, 2020). Empowering business students with QC knowledge will enable them to lead their organizations through upcoming technological transformations, ensuring they can harness the full potential of this groundbreaking technology. Besides, quantum-related experiments have been successfully run in marketing (Mo et al., 2020) and finance (Egger et al., 2021), indicating the future application of quantum technology in such domains. Business graduates aiming for roles in these domains where QC will be applied need a level of quantum awareness. While they may not be experts in quantum physics, a foundational understanding of QC will be vital. A basic understanding of quantum topics will also enable current and future talents in supply chain, marketing, finance, and IT infrastructure to collaborate and communicate with QC experts to solve complex business challenges (Mohr et al., 2022). Introducing business students as well as those from other backgrounds to QC requires having a non-physicist mindset when building the curriculum (Al-Juboori and Noonan, 2024).

Context of this Descriptive Case Study

This case study is situated at the FHNW School of Business and its Competence Center Digital Trust. Among other topics, the Competence Center engages in education and research on decentralized technologies, and artificial intelligence, and has recently expanded its scope to include QC. From its inception, the initiative at the FHNW School of Business has underscored the need for a collaborative approach in crafting a comprehensive program. Assuming the roles of host and project manager, FHNW School of Business collaborated with subject matter experts to ensure success. At the DHBW in Stuttgart, Prof. Dr. Carmen Winter and her team of lecturers, members of the Quantum BW initiative, bring valuable expertise in QC education. The QC Circle adopts a hybrid class format, facilitating interdisciplinary collaboration among students from both FHNW and DHBW. Additionally, the FHNW School of Life Sciences, represented by Prof. Dr. Clement Javerzac and his research team, operates a QC Lab in Muttenz. This state-of-the-art facility serves as both a practical learning environment and a platform for showcasing ongoing research projects.

CASE STUDY DETAILS

Course Objectives

The QC Circle targets business students at the bachelor's level, while being open to master's students and anyone with an interest in QC. As no prior knowledge is required, the course covers the fundamentals and integrates QC topics with a business perspective. Referring to the Competence Framework for Quantum Technologies from the European Commission et al. (2025), the course was targeting level A1 – Awareness Creation – with the aim to teach 1) the basic idea of QC, 2) to provide an overview of possibilities and limitations of QC, as well as 3) to interact with a QC device/platform. The detailed course objectives are outlined in Table 1.

Table 1: Learning objectives of the QC circle.

Learning Objective	Description
Knowledge and understanding	Students demonstrate basic knowledge of QC concepts (QuBit, superposition, entanglement) and of key questions addressed by the different contexts that QC is embedded in (technological, economic, and philosophical).
Application of knowledge and understanding	Students demonstrate the ability to interact with a quantum computer or a simulation. This entails simple programming tasks using a preconfigured QC platform.
Ability to judge impact, possibilities & limitations	Students demonstrate the ability to constructively discuss und judge the potential future impacts that QC might unfold on our world based on predefined factors.

Course Design

The QC Circle was structured into three sessions, each lasting for four hours. The design of each session is outlined in Tables 2–4. Columns 1 and 2 outline the topic and the contents. Given that the course was designed for a business audience without prior subject knowledge, the aim was to make the content both relevant and engaging. First, well-known concepts in the field of social sciences were integrated to help learners more easily absorb the content and understand the relevance of QC for business students (marked as (R) in col 3). Second, interactive elements were incorporated to promote engagement (marked as (E) in col 3).

Table 2: Design of session 1 of the quantum computing circle.

Topic	Content	Relevance (R) or Engagement (E)
Opening	- Course outline - Introduction round	(E) Online questionnaire collecting prior experience/-knowledge
Overview of QC	- Market overview - Technical concepts - Philosophical considerations	(R) Financial KPIs and Gartner Hype Cycle
Application of QC	- Introduction to Optimization - Optimization in QC	(R) Cost minimization business problem
Recap	- Recap of contents - Feedback and open questions	(E) Guided discussion

Table 3: Design of session 2 of the quantum computing circle.

Topic	Content	Relevance (R) or Engagement (E)
Warm-up	- Course outline - Recap/deepen of QC concepts	(R) Business problems solvable by QC concepts and (E) guided discussion
Use Cases for QC	- QC use cases - QC in life sciences	(R) Industry use cases and ecosystem review and (E) Life sciences lab tour
Practical Exercise	- QC programming - Introduction to IBM Qiskit	(E) QC programming using a visual frontend

Table 4: Design of session 3 of the quantum computing circle.

Topic	Content	Relevance (R) or Engagement (E)
Warm-up	- Course outline - Recap of contents	(E) Guided discussion
Technology Impact	- Theoretical framework - Practical Application to QC	(R) PESTEL Framework and (E) hybrid group work
Closing	- Overall reflection - Philosophical considerations	(R) Kuhn's paradigm theory and (E) guided discussion

Course Implementation

The course took place on March 18th and April 29th, 2024, and was split into half-day sessions. 52 students participated in the course (40 from FHNW, 12 from DHBW). In the first session, DHBW hosted the event, with participating FHNW students joining online from the Basel campus. In the final session, FHNW served as the host, while DHBW students joined remotely from their own campus. Before the first session, students received preliminary information via an introductory video. The initial session of the QC Circle was conducted according to the course design in Table 2. The session's lectures were delivered from Stuttgart. From Basel, a Microsoft Teams Survey was shared to gather information on the students' profiles, background knowledge, and level of expertise in physics. Of the 35 students who completed the survey, 71% stated that they know a bit of physics / they have some knowledge in physics thanks to school or work. The remainder of the session was dedicated to introducing the participants to the theoretical foundations of QC. To conclude the session, each participating institution conducted its own reflection and review, allowing for the collection of interim feedback and open questions to identify areas needing further clarification. The collected feedback informed two follow up actions: Firstly, students who opted-in received a weekly informational email titled the 'QC Monday', which primarily contextualized the topic of QC by linking it to local developments. Secondly, the feedback provided valuable inputs for the second learning session and allowed lecturers to adjust their material to better address the students' needs and interests.

The second day began with a morning session at the FHNW School of Life Sciences. Students visited laboratories to explore QC applications, from sensing machines to innovations in medical devices. Students gained insights into the impact of QC on life sciences and were introduced to the fundamentals of programming a quantum computer using the IBM Qiskit framework. In the afternoon, the third session featured a hybrid lecture held in Basel, with DHBW students participating online from Stuttgart. After an introduction to the PESTEL Framework, students from both institutions collaborated in groups to assess and discuss QC's potential impact on political, economic, social, legal, and technological landscapes. The activity prompted active participation, with students collaborating on Miro boards and communicating through Microsoft Teams. Later, the results of the group work were presented in class. The course concluded with thoughtful discussions, demonstrating the varying implications of QC on different domains. Following the QC Circle, students received certificates of attendance. A jury of lecturers evaluated the group work from the third session using predefined criteria. The best group was recognized with an award. To evaluate the program's impact, students completed a quiz one week after the course, featuring single-choice, multiple-choice, and open questions covering course content. Students were also invited to provide written feedback and suggestions for improving the QC Circle on a voluntary basis.

DISCUSSION

Students' Feedback and Learning

Following the initial theoretical input, students expressed both curiosity and apprehension regarding the complexity of the QC topic. They presented significant interest in the use cases of QC and in extended financial figures (e.g., average cost per QuBit). From a didactical perspective, maintaining the students' attention during the hybrid lecture proved challenging. While shorter inputs would have been beneficial, the concluding repetition and reflection were effective. Students also expressed a desire for more time on practical aspects of QC, reduced theoretical content, and increased opportunities for networking and collaboration. The newsletters sent between sessions were well received, and students expressed a desire to continue receiving updates. One suggestion was to divide the program into beginner, intermediate, and advanced tracks. Written feedback collected after the course indicated that students valued their participation and appreciated the course content. Moreover, they requested more content related to local contexts, such as visits to regional companies, as well as a greater focus on ethical considerations and practical use cases. The group work on the potential impacts of QC in session 3 was also well received; with students suggesting that the assessment be expanded to include impacts on specific sectors. Additionally, they recommended providing more background on current challenges, including cybersecurity. In terms of learning outcomes, the final quiz revealed a high rate of correct answers, with approximately 50% of participants scoring very well ($\geq$ 13 out of 15 points). Performance was notably higher on single-and multiple-choice questions compared to open-ended ones.

Lecturers' Feedback and Learning

From a general lecturers' perspective, it was very enriching to work together in an interdisciplinary, interinstitutional and international context. However, this required a high degree of flexibility to harmonize administrative conditions such as finding suitable time slots for joint teaching. Regarding didactics, it was a challenge for the lecturers with a technical background to present the theoretical concepts of QC in an accessible yet precise way for business students. One goal was to mathematically represent some of the unique aspects of quantum technology, such as superposition. This proved to be a significant challenge, and more time ought to be devoted to this component in future iterations. The second session highlighted the importance of incorporating interactive exercises in a QC course, particularly when the target audience has a non-technical background. As mentioned earlier, we observed a higher level of student engagement when they analyzed the implications of QC using the PESTEL framework. From a content perspective, to contextualize the current state of development, a historical overview of the relevant advances was provided to highlight the milestones and their significance. This approach proved effective in fostering understanding of current dynamics in the field of quantum technology. The findings also highlighted a current shortage of specialized personnel in fields outside of physics. The philosophical framing was also particularly valuable. The course concluded by relating to the current developments in quantum technology within Thomas Kuhn's ideas on scientific revolutions. This, together with the previously conducted PESTEL analysis in group work, allowed for consideration of societal and ethical aspects. What was initially perceived as somewhat peripheral ultimately enabled a comprehensive perspective on the technological developments discussed. This aspect will be retained in future courses.

LIMITATIONS AND RECOMMENDATIONS

Limitations

Despite the success of the QC Circle, several limitations were identified, including time constraints, content selection, limited student attention spans, challenges in managing hybrid interactions, and insufficient planning time. The course's short duration (12 hours total) resulted in dense sessions, that left some students overwhelmed and unable to fully grasp the material. Additional time and support are necessary, particularly for participants with little or no prior physics knowledge, to ensure a solid understanding of QC concepts. Nevertheless, the assessment indicated a positive learning curve. However, the mid- or long-term effects have yet to be measured. Secondly, our choice of content was another limitation, as students expressed a preference for more practical demonstrations, like the session at the FHNW lab in Muttenz. Moreover, maintaining students' focus and attention proved challenging, particularly during the first session of the QC Circle. This was primarily due to the extensive theoretical foundation of QC, which made it difficult for some students to stay engaged. Another challenge was managing interactions in a hybrid setting. Organizing physical and virtual breakout rooms across two locations required more time than anticipated. Lastly, insufficient planning time for preparation and communication between the partnering institutions hindered the alignment of content to effectively meet the needs of the target group.

Recommendations

Considering the limitations and lessons learned from running the QC Circle, we recommend the following for QC courses targeting business students. First, organizers should allocate sufficient time for thorough planning and communication between partnering institutions when designing the course and preparing the content. This becomes even more critical when the collaboration involves both a technical and a business partner/institution. The business institution should provide relevant insights into the needs of the business audience, helping the technical partner understand the participants they will engage with. Additionally, gathering the expectations of the target group should be an integral part of the planning phase. Understanding why students enrol and what they expect to gain from the course can assist organizers and lecturers in tailoring the content to better meet the needs and expectations of the attendees. Second, like Al-Juboori and Noonan (2024), we recommend that content preparation for a QC course targeting a business audience should be approached with a non-physicist mindset. The instructors should be mindful that the audience may not be familiar with certain physics concepts or QC terminology and should explain these using accessible language. Furthermore, each content module should combine a brief lecture with relatable examples, interactive exercises, and practical work. This approach will help course organizers maintain participants' attention while providing them with opportunities to gradually absorb the material. Third, the connection to economic and business concepts should be emphasized, as this is what business students can relate to. To achieve this, existing cases demonstrating how QC is applied in domains such as marketing, finance, IT, and project management should be showcased. The challenge, however, is that such cases are still in the experimental phase and are relatively few. Therefore, more research is needed in this area. Another way to sustain students' attention and interest is to design the QC course as a short-term course or workshop. This structure not only makes the course more engaging but also helps achieve the overall goal of providing business students with a foundational understanding of QC. Fourth, we recommend that organizers of a QC course for business students allocate sufficient time for interactions and networking. This provides students with an opportunity to learn from one another, particularly from those with prior knowledge. We also recommend splitting the course into different levels: beginner, intermediate, and professional. Our survey of students' profiles and backgrounds revealed that while some students already had some knowledge of physics, a few had no background in the subject. Although all participants are business students, those with prior knowledge of physics could be placed in the intermediate track, while those without could be placed in the beginner track. The professional track could be designed for business professionals who already have some interaction with QC experts through their work. Overall, future research should focus on identifying relevant QC-related content for business students. As mentioned earlier, more research is needed on case studies of QC applications in business domains for small and large corporations. Finally, further research should explore other suitable structures for organizing QC courses tailored towards a business audience. Overall, the chosen approach provided instructors with valuable practical ideas for QC education and sparked an interest in QC in business students.

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