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Independent report

# UK Quantum Skills Taskforce report

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# Foreword

Ensuring the UK has the skills to develop and adopt quantum technologies will be critical realise the benefits to society from their applications and to enable future economic growth. These advances range from new sensors to diagnose and treat diseases earlier, to an exponential increase in computing power to develop new drugs, or novel materials to reduce emissions.

The UK has benefitted from the fruits of a pioneering 10-year quantum programme, which has gifted the UK economy with a wealth of quantum talent, powering the economy and the growth of the quantum sector in the UK. This acts as a significant draw for many companies and academic groups looking to either partner with, or set up activities in, the UK.

We are at a pivot point for the sector. We cannot rest on our laurels or believe that doing more of the same will be enough. The quantum sector is rapidly developing and its skills needs are diversifying. There is a need to make sure that we are ready to adapt and meet these future demands, which will be significant. It is essential we focus sufficient time and resource to this task across the community.

There is great work underway already across the UK, some of which is showcased in this report. Throughout the work of the Taskforce I have been greatly impressed by the range of activities underway and the dedication from across the community to building opportunities to both upskill and increase awareness of the opportunities associated with these technologies. We now need to build on this and ensure activities are coordinated where necessary within a comprehensive programme of work which addresses the key issues identified in this report.

We look forward to working with the community and government throughout the International Year of Quantum, and the years to come to meet the growing needs of the sector to ensure that, ultimately, we are building a quantum-ready economy fit for the future.

I would like to thank all those who contributed their time and expertise to help to shape the report. The work collected here forms a resource we hope will inform and shape future skills policy.

**Professor Sheila Rowan CBE FRS**
Chair of the Quantum Skills Taskforce

# Executive summary

The Quantum Skills Taskforce is a sector-wide coalition, including representatives from industry, academia, professional societies, national labs, and government departments and agencies. The Taskforce has considered the current and future skills needs of the sector, and how these needs could be met.

Quantum technologies have the potential to significantly improve the productivity, security, sustainability, and health of the UK, unlocking tens of billions in economic growth while helping to address some of the country's most pressing challenges. This opportunity makes quantum technologies strategically important to the future of the UK, with nations that are early adopters likely to be at an advantage.

Building a workforce with the full range of skills required to continue leading the development of quantum technologies, and to enable their widespread adoption across industries, will be critical to realising these benefits. Over the last 10 years the UK's trailblazing National Quantum Technologies Programme (NQTP) has supported talented teams to advance cutting edge science and to build and grow innovative companies. The government is building on this success through a range of programmes, including the announcement of 5 new quantum research hubs backed by over £100 million of government funding.

The scale and breadth of the scientific, engineering, and commercial advances that have been made over the decade have transformed the skills needs of the sector. These advances have led to increases in the size of the quantum workforce and the diversity of skills required. These are likely to continue to grow at a rapid rate in the coming years. Market analysts project that new jobs created globally in the quantum computing sector reach 250,000 by 2030, and 840,000 by 2035, with many attributed to leading quantum nations such as the US and UK. This equates to a significant increase in the number of jobs in the sector globally by 2030[footnote 1].

The National Quantum Strategy recognised the crucial need to build these skills, setting out plans for the UK to become a quantum-enabled economy with access to the right skills and talent as a central pillar. The Quantum Skills Taskforce was established on the back of the Strategy. Collaboration has been central to the way we have considered these issues, engaging with over 150 representatives through a series of workshops and working group meetings.

The report summarises our findings. It is intended as a guide to enable the whole quantum sector to take these forward – the business and research institutions leading work to capitalise on the potential of quantum technologies, and the government bodies, learned societies and trade associations that are supporting them. The government will now consider these recommendations, to support and inform future quantum programmes and policy development.

To enable the current and future growth of the sector, there is a need to:

### Build on our existing strengths in quantum

- The NQTP has excelled at developing and attracting quantum specialists, with expertise in quantum physics and associated disciplines, gained through research. These individuals have been at the heart of the programme over the last ten years but are in short supply in the UK and globally. Given the nascent stage of the sector, there will continue to be a growing need for quantum specialists over the next ten years.
- Efforts to grow this section of the workforce will need to include both the development of skills domestically and the attraction of international talent given the anticipated numbers required and the global pool of excellence in research.
- Significant new investments have already been made in this area, with over £100m of funding now committed for PhD studentships and fellowships. Sustaining these investments over future funding rounds will be required to ensure long-term growth in the supply of quantum specialists and to meet the commitments to fund a 1000 PhDs in the quantum strategy.
- It is vital that the UK can continue to attract world leading talent. Programmes to attract international talent to the UK should target quantum specialists, clearly articulate the strengths of the UK quantum ecosystem, and highlight the many opportunities within quantum businesses and the new Quantum Research Hubs.

### Forge new pathways into the sector

- There is a growing demand for a broader range of skills, particularly engineering and technical skills across a broad range of disciplines. Most of these roles will not require deep expertise in quantum physics but will require some form of quantum knowledge or awareness. Many of the engineering and technical roles needed in the quantum sector will be in demand across other sectors of the economy, with evidence that there are broader skills shortages for these roles that need to be addressed.
- New pathways need to be created to better attract engineers and technicians to the quantum sector, as well as other disciplines, and to give them the quantum specific knowledge they need. These pathways should include an increase in engineering apprenticeships offered in the sector, continuous professional development training, industry placement schemes, the inclusion of quantum modules on relevant engineering degrees, and to ensure that quantum master's programmes are tailored to meet the needs of industry. There is a role for quantum industry groups to engage locally with education providers to help to shape local offers.
- There is a need to map the quantum skills and knowledge needed across the relevant engineering disciplines, to support the development of

targeted training courses and increase the awareness of opportunities within the sector.

### Prepare for the adoption of quantum computing now

- The adoption of quantum computing is anticipated to have a significant economic impact and result in a dramatic increase in demand for quantum skills across the economy – ranging for highly specialist skills to more foundational quantum knowledge and awareness. It is critical for industry to prepare for the adoption of quantum computing now, including understanding the skills they will require.
- The National Quantum Computing Centre (NQCC) will have an important role in coordinating the response to this demand, in collaboration with businesses and training providers. This includes initiatives like the SparQ user engagement programme and work to map the skills needed for adoption alongside appropriate training pathways.

### Promote opportunities and inspire the next generation

- There is a need to increase the number of young people studying and pursuing careers in STEM subjects. Ensuring that the STEM curriculum is appropriate and being delivered effectively is crucial to build the foundational knowledge needed for young people to progress into the quantum sector, a STEM role in the broader economy, or to help raise awareness amongst future users of these technologies.
- Outreach activities specifically focussed on quantum technologies, such as case studies and wider learning materials, could help to inspire the next generation of scientists, engineers and technicians. These activities are better delivered through successful, trusted, pre-existing STEM schemes where possible. To reach the greatest number of students and maximise impact, these need to be accessible by all schools, and particularly those in socio-economically deprived areas, where the provision of STEM outreach activities is likely to be more fragmented. As with wider STEM outreach activities, teacher training will be a critical component of such schemes.
- Outreach will also play an important role in attracting people already in the UK workforce to join the quantum sector. These outreach activities will need to be tailored to the specific professional communities targeted.

### Collaborate across the sector and strategically plan for the future

- Making progress on the areas identified in this report will require sustained commitment and joint efforts from organisations across the sector. The Office for Quantum in the Department for Science, Innovation and Technology should coordinate an agreed programme of work across the community to support their implementation.

- A Quantum Skills Forum should be established to facilitate the ongoing exchange of information to share best practice, monitor collective progress and ensure that the actions of government, industry, trade associations and academia are suitably coordinated and informed by the latest evidence.
- The skills needs of the quantum sector will continue to evolve as the sector develops. There is a need for a regular, sector-wide skills survey to maintain a common understanding of these changing skills needs and any emerging gaps.
- Having a diverse workforce representative of the UK's wider population will continue to be a challenge for the sector but is vital to realising the full potential of these technologies. Diversity should be embedded in all skills activities across the community, enabled by collecting diversity data.

**Table 1:** Summary of recommendations

| Priority area | Recommendations |
|---|---|
| **Improving coordination across the community** | Establish a Quantum Skills Forum with relevant trade associations, professional societies, and representatives from academia to share information and best practice on quantum skills activities. DSIT (Recommendation 15) |
| **Develop and deliver a coordinated programme of work** | Develop and coordinate a programme of work to implement the recommendations and findings made by the Taskforce and report on progress to the SAB and QSIB. DSIT (Recommendation 16)<br><br>This should include, but not be limited to, specific activities across:<br><br>Adoption:<br><br>• Expand flagship SparQ user engagement programme. NQCC working with partners (Recommendation 2)<br><br>PhD Provision:<br><br>• Consider opportunities and mechanisms for industry co-funding of PhDs and making them more accessible, visible or attractive to industry. UKRI and universities (Recommendation 5).<br><br>International talent: |

- Focus on the ‘quantum specialist’ roles across a wider range of target countries. DBT (Recommendation 9)

Engineering and technical skills:

- Develop short quantum modules for apprentices and Degree programmes. (Recommendation 10 and 11)
- Work with relevant partners to develop and publish the technical career pathways relevant to the quantum sector, signposting existing occupational standards and training opportunities. DSIT (Recommendation 11)
- Establish which bodies are best placed to accredit quantum engineering degrees and master’s programmes and design Master’s for industry’s needs. DSIT with the Engineering Council (Recommendation 12)
- Explore the merits of establishing an industry placement scheme for the quantum sector. DSIT (Recommendation 13)

Outreach activities

- Agree priorities for and develop both educational and promotional outreach material, building on existing efforts. DSIT with NQTP partners and the wider community (Recommendation 14)

Evidence and evaluation: See section below

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**Understanding the skills needs of the sector**

The evidence and evaluation workstream of the skills programme should include work to:

- Identify and map the specific quantum skills and knowledge that are required by different engineering disciplines, as well as the pathways into the sector. DSIT with the relevant learned and professional societies (Recommendation 1)
- Run a regular skills survey. DSIT with relevant trade associations, learned societies, and research councils to (Recommendation 4)
- Publish a landscape review of publicly funded PhD-level quantum skills activities and fellowship

| | |
|---|---|
| | programmes relevant to the quantum sector. UKRI (Recommendation 6)<br>• Map the skills needed to adopt quantum computing in priority industries. NQCC (Recommendation 2)<br>• Undertake further analysis on the size and composition of the academic workforce, including technicians<br>• Explore whether the number and type of visa issued to workers in the quantum sector can be tracked. DSIT and Home Office |
| **Principles and best practice to adhere to** | The report suggests a range of principles and best practice to adhere to across the sector:<br>All<br>• Ensure that skills programmes are designed to enable and encourage participation by a diverse range of people. The community should be encouraged to collect diversity data. (Recommendation 3)<br>Academia<br>• Continue to follow the recommendations identified by the UK ITSS, TALENT Commission and the Technician Commitment to support the quantum technician workforce and share best practice. (Recommendation 8)<br>Industry<br>• Invest in apprenticeships where they align with their workforce needs, particularly for the 5 roles identified by the Taskforce<br>• Consider industry placements as they offer valuable opportunities for interns to gain new skills and a better understanding of working in the quantum sector |

# Introduction

Quantum technologies have the potential to profoundly change our lives and to help address some of the most pressing challenges we face as a society. Over the next 10 years this innovative group of technologies present a significant opportunity to improve the health, security, sustainability, and prosperity of the UK. The impact of quantum technologies is anticipated to grow further over time, with the potential for transformative increases in our standard of living, productivity and growth.

The UK has long recognised the strategic importance of quantum. The flagship National Quantum Technologies Programme (NQTP) was the world's first national major quantum programme when it was established in 2014. With over £1 billion invested over 10 years, it has given the UK a leading position in the research, development and early commercialisation of quantum technologies[footnote 2]. The government is now building upon this success, with new steps to help ensure that the UK can capitalise on the enormous opportunities offered by these technologies and transform into a world-leading quantum-enabled economy[footnote 3]. The UK will only be able to achieve this ambition and benefit from the potential of quantum if we can develop a workforce with the appropriate skills and knowledge.

Recognising the importance of skills to delivering on the UK's ambitions for growth and benefits from these technologies, the National Quantum Strategy committed to several targeted skills investments. It also articulated plans for a Quantum Skills Taskforce, to help to understand the changing skills needs of the sector and to undertake detailed reviews into the actions required to address these.

In November 2023, this Taskforce was established with representatives from UK Research and Innovation (UKRI), Institute of Physics (IoP), Royal Academy of Engineering (RAEng), TechUK, UKQuantum, Department of Science, Innovation and Technology (DSIT), Department for Education (DfE), and Department for Business and Trade (DBT), chaired by Professor Sheila Rowan FRS. Collaboration has been central to the work of the Taskforce, which has brought together over 150 stakeholders from across academia, industry, learned societies, national laboratories, and government departments.

The Quantum Skills Taskforce report is a product of this collaborative effort. It provides a high-level overview of the UK quantum ecosystem, before setting out findings on the current and future skills needs of the sector. It then considers how these skills needs can be met by building upon our strengths in quantum, by forging new pathways into the sector, by promoting the exciting career opportunities available, and by building upon the collaboration that has made this report possible.

# Quantum technologies in the UK

## What are quantum technologies?

Quantum technologies exploit the unique properties of quantum mechanics, the behaviour of atomic and sub-atomic particles, to deliver technological capabilities. Many technologies that are already part of our everyday lives make use of quantum mechanics indirectly. These are sometimes known as first-generation quantum technologies and include many devices which have been foundational to modern life and underpin the way we live today, such as semiconductors and lasers.

The quantum sector is focused on developing and deploying the second-generation of quantum technologies. These seek to utilise, generate, detect or control the novel effects of quantum mechanics, such as entanglement and superposition, to make new advances with the potential to be transformative for society across a range of areas. Examples of these quantum technologies include quantum computing, quantum sensing, imaging and metrology, and quantum communications.

- Quantum computing: Quantum computing will enable simulating complex environments or phenomena (like chemical reactions for drug discovery or materials design); optimising processes or services (such as energy networks); or as part of AI systems (for instance to support self-driving vehicles). Quantum computing is anticipated to create significant global value, with some estimates that it could create up to $850 billion of productivity gains by 2040[footnote 4].
- Quantum imaging, sensing and metrology: quantum sensors can make highly sensitive measurements of emissions and pollutants in the environment, a patient’s health, inertial position, or the structural integrity of railway, highway or other types of infrastructure. These technologies are estimated to generate at least $5 billion in revenue globally by 2030[footnote 5].
- Quantum communications: quantum communications can support the secure exchange of sensitive information such as personal, commercial, financial or health information. These communications technologies are projected to generate at least $8 billion in global revenue by 2030[footnote 6].

## Defining the quantum sector

There are a growing number of businesses and research institutions involved in the research, development and adoption of quantum technologies in the UK. The sector is made up of:

- research institutions and national laboratories that are leading foundational research relevant to quantum, supporting translational collaborative development activity, and identifying potential applications.
- companies that are involved in the quantum technologies supply chain, such as those in the photonics sector.
- smaller companies that typically focus exclusively on the development of quantum technologies and the identification of use cases.
- larger companies that work on the development and adoption of quantum technologies and applications as one part of a broader range of business operations.
- a range of organisations that are considering how they can adopt and benefit from quantum technologies.

There are at least 160 companies within the UK quantum sector, with more than half of these headquartered outside of London and the Southeast of England[footnote 7]. The UK quantum sector is spread across several leading clusters, including the Central Belt of Scotland, North West England, South Wales, London, Oxfordshire, Cambridgeshire, North East England, and Bristol. These clusters are set out in the map at Figure 1 below[footnote 8].

### Figure 1: Quantum innovation clusters


## National Quantum Technologies Programme (NQTP)

The UK was one of the first countries to establish a national programme, the NQTP. We have made great progress through this trailblazing research and development programme, backed by a £1 billion investment between 2014 and 2023[footnote 9].

The NQTP recognised early that people and knowledge are a critical element in supporting the emerging ecosystem, with skills programmes making up a central pillar of the NQTP. Investments in skills have had a strong focus on developing quantum expertise, with over 570 PhD studentships and 30 fellowships supported between 2014 and 2023 as well as three dedicated Training and Skills Hubs in quantum systems engineering.

These early investments have resulted in a vibrant and rapidly growing sector. The UK is home to the second largest number of quantum companies in the world and has attracted the highest level of private investment in Europe[footnote 10]. This vibrant ecosystem is backed by research excellence, with the UK being third in the world for the impact of our quantum research[footnote 11]. The UK also has the highest concentration per capita of talent relevant to the quantum sector[footnote 12].

These early investments have resulted in a vibrant and rapidly growing sector. The UK is home to the second largest number of quantum companies in the world and has attracted the highest level of private investment in Europe[footnote 8]. This vibrant ecosystem is backed by research excellence, with the UK being third in the world for the impact of our quantum research[footnote 8]. The UK also has the highest concentration per capita of talent relevant to the quantum sector[footnote 9].

# Skills needs of the sector

The quantum sector is at a nascent stage, but it is developing and growing rapidly. These changes have been driven by significant scientific and engineering advances, alongside increases in public and private funding and an increased focus on the commercialisation of these technologies. As quantum technologies have advanced, the demand for suitably qualified candidates has increased dramatically[footnote 13], and the skills needed by the sector have diversified. A wider range of STEM skills are increasingly in demand across the sector. Based on 2022-23 data from HMRC, the UK quantum sector employs around 1,700 people, with an average salary of approximately £60,000[footnote 14]. Projections from The Quantum Insider suggest that the number of new job roles in quantum computing specifically globally is anticipated to reach 250,000 by 2030, and 840,000 by 2035, with a significant proportion of these likely to be in leading quantum nations such as the US and UK[footnote 15].

The sector’s early stage of development and rapid pace of advancement has contributed to it being a vibrant, dynamic and exciting area to work in. It has also made it difficult to accurately quantify the size and characteristics of the workforce, and to understand the changing skills needs of the sector. The Taskforce has sought to address this through a series of skills workshops, focused on the current skills needs of the sector, how these needs may change over time, and the relevant skills training pathways.

While the Taskforce has focused on the scientific, engineering and technical skills requirements of the quantum sector, a broader range of roles are required across the ecosystem. These include those with commercial and product development expertise, intellectual property lawyers, supporting corporate functions, and suitably qualified STEM teachers. Most of these roles will only require an awareness or understanding of quantum technologies, rather than in-depth quantum knowledge.

We have identified nine broad classifications of scientific, engineering, and technical roles that are relevant to the sector at this point in the development of the field, set out in Table 2 below, alongside examples of relevant roles. The Taskforce had broad agreement on these classifications of role. It should be noted that there is considerable uncertainty on the skills required in the future and the size of the future workforce. As such, the skills needs of the sector should be considered a snapshot at a moment in time, rather than a definitive list.

| Broad classification | Examples of roles[footnote 16] |
| --- | --- |
| Quantum specialists | Quantum algorithms scientists<br>Experimental quantum physicists<br>Quantum photonics, electronics, and control engineers<br>Quantum cryptography/cyber security |
| Electrical and electronics engineering | Electrical and electronics engineers<br>Photonics engineers<br>Radio frequency engineers<br>Electrical and electronics technicians |
| Mechanical engineering | Mechanical engineers<br>Cryogenics engineers<br>Vacuum engineers<br>Engineering technicians |
| Software engineering | Software engineers<br>FPGA engineers<br>DevOps engineers |
| Systems engineering | Systems integration engineers<br>System design engineers<br>Application engineers |
| Other engineering roles | Nanofabrication engineers<br>Packaging engineers<br>Integrated circuit design engineers |
| Material science and chemistry | Computational materials scientists<br>Experimental materials scientists<br>Synthetic chemists<br>Materials chemists |
| Quality control and regulation | Quality control and planning engineers<br>Quality assurance and regulatory professionals<br>Quality assurance technicians<br>Planning, process and production technicians |

| Broad classification | Examples of roles[footnote 16] |
| --- | --- |
| Other laboratory roles | Laboratory technicians<br>Technician scientists |

## Quantum specialists

A wide range of skills and knowledge is included within our 'quantum specialists' classification. We consider these to include all roles with highly specialised quantum skills and knowledge, which is typically gained through a PhD in quantum sciences or a closely related field such as physics or maths. Examples of these roles include quantum algorithm scientists, quantum photonics engineers, and experimental quantum physicists.

It takes significant time for candidates to gain the appropriate knowledge and skills for these roles, with some requiring additional post doctorate research or industry experience. This group of roles is typically instrumental in research and development, working at the cutting edge of the sector. Individuals in these roles have played a major role in the development of the sector and will continue to do so in the future.

There are a range of important niche roles within the quantum specialist classification, which we have not listed in full. As these roles are at the cutting edge of research and development, the skills and knowledge required to undertake them changes in response to scientific and technological developments. The Taskforce has not found a need for a comprehensive taxonomy of skills to be developed for quantum specialist roles, as this would be quickly outdated.

The UK has one of the highest number of graduates globally that are relevant to the sector, so is starting from a good position[footnote 17], but demand for quantum specialists is high and anticipated to continue growing for at least the next ten years[footnote 18]. This is because many quantum technologies are still at a low technological readiness level (TRL), where new opportunities emerge, there will continue to be a heavy focus on research and development, and a reliance on those with expertise in quantum physics. There is a limited supply of candidates with this deep expertise in quantum globally, with many roles in high demand in countries with established quantum sectors[footnote 19].

> **Finding:** There will continue to be a need for quantum expertise grounded in physics and mathematics to support the growth of the sector, at least in the near and mid-term. Quantum specialists make up

> a significant proportion of the workforce and demand for their skills will continue to grow as the sector does. The UK will rely on both international and domestically trained talent to meet the demand for these roles.

## Engineering roles

Over recent years there has been a growing need for engineering roles within the quantum sector. These needs cover a wide range of engineering disciplines and associated levels of training, from technicians through to professors of engineering and those with significant industry experience.

Engineering and technical roles will be pivotal in advancing the technological readiness level of quantum products, improving performance, miniaturising these technologies where needed, and producing them at scale. Engineers and technicians will be needed to address some of the most pressing challenges faced by the sector, including scaling the number of qubits within quantum computers, integrating quantum sensors into existing systems, packaging technologies to work in a broader range of settings, optimising manufacturing processes and ensuring consistent product quality[footnote 20], many of which were highlighted in the Royal Academy of Engineering Report on quantum infrastructure[footnote 21].

Demand for engineers and technicians within the quantum sector is likely to increase significantly over the next ten years. As the sector continues to scale, the number of engineers and technicians needed within the sector is likely to be greater than the number of quantum specialists.

The level of quantum knowledge required will vary significantly depending on the role, the engineering discipline, and the area of quantum technologies they are working on. Some roles will only require an awareness of quantum, while others will require more substantial knowledge.

> **Finding:** The demand for engineering and technical skills will grow in scale in the future across a broad range of engineering disciplines. Most of these roles will not require deep expertise in quantum physics but will require some form of quantum training. This could take place through on-the-job training, through short courses, or as part of degree programmes. To support the development of more targeted training courses and increase awareness of opportunities for engineers and technicians within the sector, there is a need to understand role specific requirements in greater detail.

> **Recommendation 1:** DSIT should work with the relevant learned and professional societies and engineering bodies to identify and map the specific quantum skills and knowledge that are required by different engineering disciplines to work within the quantum sector, as well as the pathways into the sector.

Several engineering and technical roles were viewed as difficult to recruit within the quantum sector. There may be a lack of awareness of career opportunities for engineers within quantum as well as perceptions that these roles require significant quantum expertise. This could be exacerbated by wider engineering skills shortages across the economy, with increasing demand for these roles within several other sectors [footnote 22][footnote 23][footnote 24].

> **Finding:** It is important that demand for engineering roles in the quantum sector is considered as part of a broader, economy wide assessment of engineering skills needs.

## Quantum computing

Quantum computing is currently anticipated to have the largest economic impact of all quantum technologies[footnote 25]. It has also been the main contributor of increases to the number of job vacancies in the quantum sector in recent years[footnote 26]. This is because the levels of investment into quantum computing companies is greater than the investment into other quantum companies[footnote 27], likely in anticipation of these economic opportunities. Given the expected impact of quantum computing, it is probable that it will continue to be a significant driver of increases in demand for quantum skills.

Some of the largest long-term increases in demand for skills may be associated with roles that enable the adoption of quantum computing and the development of use case applications. Those sectors most likely to be impacted by quantum computing are now starting to upskill in anticipation of the arrival of general-purpose machines in the future[footnote 28]. The knowledge and skills needed to do some of these roles is also likely to change significantly, with quantum computing anticipated to become more accessible as the technology matures and user interfaces improve. Sustained examples of quantum systems having an advantage over classical computers, and the development of error-free quantum computing could act as an inflection point for these changes in the scale of the demand.

While there is still significant uncertainty on when these technological milestones will be achieved, they could cause a sudden increase in demand for relevant skills within the sectors most affected[footnote 29]. An example of such a situation arose with the increased demand for AI skills after the breakthrough of large language models in 2022.

> **Finding:** Skills for the adoption of quantum computing are an important component of future demand. There is a need to ensure that we better understand the skills needed to adopt quantum computing across the economy. We must also consider the training pathways that could be used to upskill existing workers in the industries that are most likely to benefit from the adoption of quantum computing.

Building this knowledge now should contribute to a skills system that is responsive to any future increases in demand and should minimise the risk that potential skills gaps will hinder adoption. This will be vital in enabling the UK to be a leading nation in the adoption of quantum computing and unlocking significant potential economic and societal gains as a first mover.

> **Recommendation 2:** The National Quantum Computing Centre (NQCC) should expand their flagship SparQ user engagement programme and map the skills needed to adopt quantum computing in priority industries. This should consider how these relate to existing digital skills and the most appropriate training pathways.

**Case study - UK Quantum Hackathon**

The UK Quantum Hackathon is the NQCC's flagship annual event, delivered as part of the user engagement programme, SparQ. The event brings together teams of aspiring coders with industry mentors to tackle practical challenges and develop solutions using quantum computing. Aimed at students and early career researchers, participants gain hands-on experience, advancing their skills in areas such as developing mathematical models for quantum computing, using quantum algorithms, coding with quantum computers, and benchmarking of their results.

The 2024 event ran over 3 days, with participants working on problems in areas as diverse as healthcare, energy, and engineering. By ensuring that a broad range of industries are represented in the problem challenges and a variety of quantum computing platforms are available, the hackathon offers an opportunity for participants to explore the potential of current quantum computing technology. As well as exploring the technical aspects of use case development, participants are encouraged to consider the need for responsible and ethical quantum computing. They considered this within the context of use case development and quantum programming, emphasising the responsibility of the quantum computing community to ensure that the technology is used responsibly, safely, and for the benefit of society.

| Year | Coders | Industry use cases | Quantum computing platforms |
|---|---|---|---|
| 2022 | 44 | 6 | 4 |
| 2023 | 55 | 10 | 7 |
| 2024 | 69 | 13 | 8 |

## Diversity in the sector

There is no comprehensive data on the diversity characteristics of the UK quantum workforce. However, we can infer some trends from data on Standard Occupation Classification (SOC) codes, information released by the Higher Education Statistics Agency (HESA), and data on the broader STEM workforce. Across all 1.2 million of those employed in the SOC codes identified as relevant to the quantum sector, 19% are female (compared to 48% across all occupations)[footnote 30]. Analysis of HESA data shows that quantum courses have a significantly larger percentage of male students than most related subjects[footnote 31]. This indicates that the pipeline of quantum talent continues to be more heavily skewed towards men.

From demographic information on the broader science, technology and engineering workforces which acts as a pipeline for quantum talent, we can also infer that the quantum workforce is likely to be unrepresentative of the broader UK workforce. For example, 65% of the STEM workforce are white men[footnote 32] and women make up 15.7% of engineering workers[footnote 33].

As set out in government's mission to break down barriers to opportunity, a diverse workforce is foundational to the realisation of innovation and growth across the economy. This report has set out the diverse range of skills required by the sector, but it will also be important for the workforce to be made up of individuals with a diverse range of experiences, backgrounds, and to operate with a diversity of thought. These diverse perspectives should contribute to innovative problem solving and creativity[footnote 34], to maximising the economic[footnote 35][footnote 36], and social impact of quantum technologies, and to increasing public understanding of quantum[footnote 37][footnote 38][footnote 39].

> **Finding:** Having a diverse workforce representative of the UK's wider population has been and will continue to be a challenge for the sector, but is vital to its future success and realising the full potential of these technologies.

> **Recommendation 3:** Across the range of activities within the quantum programme, and the community as a whole, to train and recruit talent, efforts should be made to ensure they are designed to enable and encourage participation by a diverse range of people. The community should be encouraged to collect diversity data.

## Changing needs of the sector

The Taskforce has brought together significant evidence on the quantum workforce built upon extensive analysis and stakeholder engagement.

However, due to limitations in the data available, this is not always comprehensive. Information of the future skills needs of the sector should particularly be considered as a snapshot in time, with the skills needed likely to change further as the sector continues to innovate and rapidly grow.

> **Finding:** There is a need to continue monitoring the skills needs of the sector as these develop, and to explore opportunities to improve the data held on the workforce.

> **Recommendation 4:** DSIT should work with relevant trade associations, learned societies, and research councils to run a regular skills survey. This should maintain an up-to-date understanding of the skills needs across the sector, the workforce challenges experienced by both industry and academia and improve information on the workforce. DSIT should also continue to explore other opportunities to develop and access robust data on the quantum workforce. This work should complement Skills England's unified assessment of skills needs, and other skills mapping being undertaken across government.

The frequency of the survey should balance the need for up-to-date information on the sector, while minimising the administrative effort required to complete it.

# Building on our strengths in quantum

The UK has significant strengths in our academic workforce, evidenced by the global impact of our research in quantum technologies and well-established programmes to support PhD studentships and early career researchers under the NQTP. DSIT analysis shows that the UK ranks third for the impact of its quantum technologies research[footnote 40].

The vibrant UK quantum ecosystem, both within academia and industry, has also benefitted from attracting top international talent as a result of the programme. So how do we ensure that we continue to deliver an increasing number of suitably trained physicists, engineers and mathematicians at PhD level and above to meet the needs of the sector, building upon these existing strengths?

Over the first 10 years of the NQTP, the UK has funded over 570 PhD studentships in quantum technologies and over 30 research fellowships. These investments in developing individuals with deep quantum specific expertise have contributed to the UK's leading global position. However, as is common with many other nations, there is some evidence to suggest this supply has not been sufficient to meet the rising demand for quantum specialists in the UK[footnote 41][footnote 42] and globally[footnote 43].

## PhDs

The Taskforce welcomes the commitment made in the National Quantum Strategy to fund over 1,000 PhD studentships between 2024 and 2034, and investments in Centres for Doctoral Training (CDTs) and Doctoral Training Partnerships (DTPs) announced in 2024 which mean the UK in currently track to meet this commitment. These increases in funding will substantially boost the supply of individuals with quantum expertise, but it is not yet clear whether this will be sufficient to meet future demand, given the rapidly growing sector. There will be a need to continue to monitor and revisit the situation in the coming years and plan accordingly.

Funding PhD studentships using a mix of both CDTs and DTPs has been welcomed by the community. This mixed approach should give candidates greater choice when searching for a PhD that best meets their interests and aspirations, while also allowing a much wider range of universities to offer funded quantum PhDs.

### Explainer – Support for PhDs

CDTs and DTPs are the mechanisms most used by EPSRC to support PhD studentships in quantum technologies. To harmonise terminology across the UKRI portfolio, CDTs have recently been renamed as Doctoral Focal Awards, while DTPs have been renamed as Doctoral Landscape Awards. Within this report have continued to use the old names for these programmes for clarity, as these are likely to be more recognisable to the quantum community.

CDTs deliver cohort-based training in areas where both breadth and depth of research training are required. Students also receive additional training and support in areas such as entrepreneurship, responsible innovation, and science communication. The CDTs typically support around 5 cohorts, with each cohort including at least 10 students. CDTs include co-funding of between 20% and 50%, and typically provide opportunities for students to collaborate with industry or research partners.

DTPs provide funding to UK universities to support multiple studentships. They are flexible awards to support doctoral training in any relevant areas of engineering and the physical sciences. The university holding a DTP manages the advertisement of opportunities and recruitment to studentships funded through the DTP. They determine the length of studentships, stipend levels, and the allocation of studentships within their organisation.

Other mechanisms used to support quantum PhDs include Industrial Cooperative Awards in Science & Technology (ICASE), and PhDs supported directly by NQTP partners, such as the National Physical Laboratory (NPL) or the Defence Science and Technology Laboratory (Dstl).

Some of the strengths associated with the CDT model could potentially be replicated for other PhD routes, some of which are already being rolled out in different areas. The provision of additional cohort-based training opportunities in complementary areas, including entrepreneurship training, is one significant benefit highlighted by those receiving the training[footnote 44]. Another is that CDTs present an accessible and attractive way for industry partners to co-develop and co-invest in PhD training, which may include the opportunity for students to undertake industry placements[footnote 45].

Quantum SMEs have highlighted that they find it particularly challenging to co-invest in PhD routes other than CDTs. There is a perception that some PhD routes, such as ICASE, favour larger organisations over the SMEs that make up the majority of the quantum sector.

> **Finding:** CDTs and DTPs both offer attractive packages for PhD studentships. There are benefits to students around cohort-based training at PhD level and appetite from SMEs to co-fund PhD places but perceived barriers to them doing so at a system and university level. The Taskforce welcomes the introduction of UKRI’s new deal for postgraduate research, which is likely to provide additional opportunities for complementary training.

> **Recommendation 5:** UKRI should consider opportunities and mechanisms for industry co-funding as part of UKRI PhD programmes, and how these could be made more visible to industry and accessible to SMEs. The impact of existing co-funding requirements should be reviewed to ensure they are not inadvertently limiting the level of industry investment that universities can attract. Universities should consider how they could make industry more aware of co-funding opportunities.

There have been several welcome investments made across the NQTP’s skills programmes in 2024, including the establishment of new CDTs and funding for skills within the new Quantum Research Hubs. However, there is currently a lack of understanding of the full range of PhD-level skills activities that are being funded across the NQTP, and whether there are any gaps in provision, particularly in skills shortage areas like algorithms design or engineering disciplines. The Taskforce has not been able to undertake a review of provision due to the timing of the launch of the Research Hubs and CDTs.

> **Finding:** There is a need to better understand PhD-level skills provision across the quantum programme and whether it is addressing identified gaps in skills.

It would be beneficial to develop a common understanding of PhD-level quantum skills activities across the UKRI portfolio, as well as across other providers. This should be published and highlight opportunities for further complementary training, in areas such as entrepreneurship and commercialisation. This will help to increase awareness of opportunities and identify any gaps in provision to be addressed through the next tranche of skills investments.

> **Recommendation 6:** A landscape review of publicly funded PhD-level quantum skills activities should be published, alongside a gap analysis on the fellowship programmes relevant to the quantum sector.

## Academic workforce

Historically academia has been a provider of skills both for academia itself and the quantum workforce in industry. Over the past few years, a significant number of academics have either spun out companies or become affiliated with them, and industry has become a significant draw for academics more widely given the salaries offered. There is a risk therefore that the academic base becomes depleted, and lacks the talent needed to train the next generation of leaders, or that we have a higher flow of talent out of the UK academia to overseas research institutions, than the flow inwards.

While the Taskforce is anecdotally aware of the overall size of the academic community and specific skills gaps, primarily caused by senior academic staff leaving leadership roles, there is very limited data on the academic quantum workforce or how it has changed over time. The volume of quantum scholarly output with UK authorship has grown since 2014, but this mirrors the trend in quantum scholarly output globally[footnote 46]. This lack of conclusive evidence has prevented the Taskforce from assessing the impacts of academic skills gaps on the delivery of quantum research and teaching activities.

Several universities indicated to the Taskforce that they would have capacity to train more students if additional funding was available, although this would need to be staggered over several years due to the absorptive capacity of a relatively small system, and mindful of wider pressures on the system. Surveys of doctoral students suggest that many continue to be interested in pursuing academic careers. However, given the small size of the global quantum talent pool and the growing demand for skills, it is likely that it will become more challenging to attract and retain world-leading researchers within UK research institutions.

We know that having a leading long-term quantum programme that gives academics the opportunity to work on ambitious and interesting scientific problems acts as a significant draw for researchers into the country and helps to retain talent. The recent launch of the 2024 Quantum Research Hubs is anticipated to help attract more talent in the future. Setting out wider plans for the future national programme will also contribute to the UK retaining and attracting talent.

> **Finding:** There is a need to better understand the composition of the academic workforce in the UK to inform any future activity designed to ensure it remains competitive. It would be beneficial to articulate the opportunities and benefits of the UK ecosystem. The workforce needs of academia should be monitored as part of the skills survey proposed in

> recommendation 4 of this report, and further HESA analysis would be beneficial on the academic workforce.

It will be important for leaders within the university sector to ensure that academia is an inclusive and attractive place to work, as set out in the Royal Society report on research careers[footnote 47]. This is not specific to quantum. There are several ways in which this could be done, with Taskforce participants highlighting the need to recognise research experience gained within industry during recruitment, to allow talented staff to pursue other opportunities through fractional appointments which enable them to move freely between academia and industry, and initiatives to improve the retention of female researchers.

> **Finding:** The Taskforce endorses the Royal Society report on research careers and commends it to university leaders looking to retain future leaders.

## Fellowships

There are several fellowship programmes relevant to the quantum sector. These are provided by UKRI, EPSRC, the Royal Academy of Engineering (RAEng) and the Royal Society. Stakeholder feedback indicates that these fellowships have provided an excellent mechanism to attract, develop and retain the best and brightest quantum talent within the UK. These programmes have been effective in supporting talented individuals to establish and develop their research careers in the UK and similar programmes should continue to be funded in the future.

> **Finding:** Future fellowship schemes should be based on these examples of good practice, accessible to academia and industry and should not be overly prescriptive in their focus. They should generally be used to support research excellence or curiosity-led research as the primary driver, and should not be directed exclusively at applied research, as there are opportunities to pursue applied research in other areas of the NQTP. Some fellowships allow greater flexibility on the activities, equipment and support staff that can be funded, which typically make them more attractive to senior researchers.

Similar to PhD level training, the development of early career fellows could be further supported through additional community building activities. These activities could help to build professional networks between some of the sectors potential future leaders, support knowledge exchange, and focus on relevant training or briefings. This activity would be particularly beneficial for the larger cohorts of fellows supported by EPSRC's quantum specific fellowship programmes.

> **Finding:** Community building activities are also important for early career fellows.

> **Recommendation 7:** Providers, including EPSRC, should explore whether there is value in more community building activities to support the broader development of early career fellows

## Technicians in the academic workforce

Technicians make up a core part of the academic workforce, enabling both teaching and research activities. While there is a shortage of relevant technicians across the quantum sector and the broader economy, anecdotal feedback indicates that this shortage is particularly acute within higher education and research institutions. Further analysis is required to better understand the situation for institutions undertaking quantum research.

Initiatives such as the UK Institute for Technical Skills and Strategy (UK ITSS), the TALENT Commission, and the Technician Commitment are aiming to address this shortage and the Taskforce is supportive of these efforts. They are doing so by advocating for the technical community, with the aim of accelerating and advancing technical skills and careers through insights, influence, innovation and integration.

> **Finding:** Stakeholder feedback indicates there is a potentially acute shortage of technicians in academia. It will be important to monitor whether existing initiatives such as UKITSS and the Technician Commitment are having the desired effect and to consider if specific actions are required in institutions undertaking quantum research.

> **Recommendation 8:** There is a need to ensure that quantum is a great place to work for technicians in research. Relevant academic departments should continue to follow the recommendations identified by the UK ITSS, TALENT Commission and the Technician Commitment to support the quantum technician workforce. DSIT and UKRI should

> support those universities to adopt these recommendations and share good practice on their implementation.

DSIT should work with the UK ITSS to gather further evidence on the quantum technician workforce in academia as part of wider efforts to improve evidence about the sector.

**Case Study - UK Institute for Technical Skills and Strategy**
The UK Institute for Technical Skills & Strategy (UK ITSS), established in August 2023, is a national entity driving strategic change for the UK's technical workforce in higher education and research. Building on the legacy of the Research England funded TALENT Programme and now hosting the Technician Commitment, UK ITSS addresses the urgent need to make technical careers more visible, attractive and supported.

Technical professionals play a critical role in delivering the UK's research, innovation and economic growth ambitions, particularly in the development and implementation of critical technologies.

UK ITSS is delivering against seven strategic priorities: policy influence, learning and development, education pathways, community building, consulting, international engagement and the Technician Commitment.

Activities include flagship and unique technical leadership programmes, a national Technical Capability Showcase of over 200 facilities, and a thriving international knowledge exchange placement scheme. Through its Research and Policy Group, UK ITSS provides evidence-based insights to shape policy, while its Education and Career Pathways Lab is supporting apprenticeships, T Level placements and improved career entry routes and pathways.

Thousands of technical professionals have already benefitted from UK ITSS programmes, and over 130 institutions are signed up to the Technician Commitment, signalling growing momentum for cultural change.

UK ITSS is tackling sector-wide challenges such as skills shortages, lack of career progression, and underrepresentation, while helping institutions embed strategic workforce planning.

In doing so, it is strengthening the UK's global leadership in technical skills and ensuring the technical workforce is equipped to drive innovation, productivity, and long-term economic prosperity.

## International recruitment and retention

The UK quantum sector has benefited from being able to attract some of the best and brightest talent from around the world and is dependent on the continued supply of both domestic and international talent[footnote 48]. Overseas talent has collectively made huge contributions to the UK quantum ecosystem, both within academia and industry. Ensuring that the UK can continue to both attract and retain this talent will be important to support the development of the national quantum sector.

The previous section highlighted that many of the roles that are most in demand within the quantum sector require highly specialised, cutting-edge skills, knowledge and experience. It can take several years to develop these skills, with only a small number of individuals globally having the skills and knowledge required for some roles. These highly specialised workers can have an outsized impact on the development of the sector, and are likely to be in high demand globally, with companies and research institutions in multiple countries competing to attract the same individuals.

## Attracting top talent

The UK Global Talent Network (GTN) which launched in 2021, aimed to proactively attract and support the best internationally mobile science and technology talent to relocate to the UK. Quantum technologies was 1 of 3 priority sectors for the GTN, alongside artificial intelligence and life sciences.

The GTN's efforts to attract talent focussed on the United States and India. Taskforce members have identified challenges and limitations associated with focusing talent attraction on only 2 countries and believe that a wider geographic focus would be beneficial. There are opportunities to partner with countries that are developing academic quantum capabilities, but do not yet have a quantum industrial base. Such partnerships could allow the UK to attract leading talent from these nations, while supporting the development of their respective quantum ecosystems. Several examples of nations in this position exist across Southern and Eastern Europe.

> **Finding:** While the skills needs of the sector are diversifying, the Taskforce finds that efforts to attract international talent should focus on quantum specialist roles at this time. This is due to the long time required to develop these skills domestically, and their relatively limited availability. The specific specialist roles targeted should be kept under

review, guided by the results of the regular skills survey. There are also benefits from focussing efforts on a wider geographic pool, such as accessing a larger pool of potential talent. As time goes by it may be necessary to refocus efforts towards attracting wider skills in engineering to scale for example.

**Finding:** It will be important to promote the broader benefits and attractiveness of life in the UK to further support the attraction of future quantum leaders. It will also be important to better showcase the strength of the UK quantum ecosystem and the exciting career opportunities within it.

**Recommendation 9:** Government efforts to attract international talent should focus on the ‘quantum specialist’ roles for which there are domestic skills shortages. These efforts should have a wider geographic focus beyond the US and India, including countries that have developing academic capabilities but do not yet have a commercial quantum industry. They should also provide additional information on the attractiveness and benefits of life in the UK, alongside further information on the strength and dynamism of the UK quantum sector.

## Visa routes and costs

Stakeholders across the sector have highlighted the Global Talent visa as an attractive route for international talent, which is open to leaders or potential leaders in science and technology. The launch of the new Future Technology Research and Innovation (FTRI) Government Authorised Exchange (GAE) has also been welcomed by the sector. This scheme allows suitable businesses to sponsor researchers and post-graduate students for temporary placements of between 1 and 2 years, depending on the activities undertaken. While some stakeholders have said the immigration system compares favourably to some other major economies, others have noted challenges around the length of time it takes to secure a visa and the complexity of navigating the visa system.

Many stakeholders have raised concerns that the overall cost of the immigration system acts as a barrier to attracting and retaining talent to the UK, with particular concerns around the upfront cost of the Immigration Health Surcharge (IHS), when compared to schemes in other countries. It is difficult to make comparisons between different countries’ immigration fees, as immigration systems and fees are complex, with visa fees varying considerably, usually dependent upon the particular circumstances of an applicant. Analysis undertaken by the Royal Society[footnote 49] suggested the total upfront costs for a UK visa are higher than other comparable countries however, their analysis does not compare like with like. The report states that no 2 visa systems are directly comparable, and that it did not account for costs incurred over the whole period of the visa, including ongoing costs such as mandatory healthcare premiums that are payable in some countries.

The cost of the IHS is equivalent to the estimated average annual cost of providing healthcare to those coming to the UK, and has raised £6.9 billion for healthcare spending since 2015[footnote 50].

> **Finding:** Analysis currently available does not demonstrate a link between upfront immigration costs and the level of migration, although we have heard some anecdotal accounts that high upfront immigration costs act as a barrier to retaining and attracting overseas talent. We heard accounts of challenges around the time it takes to secure a visa, however visa processing times are favourable when compared to the UK's global competitors, with visas consistently processed within those published service level agreements. It's important to keep under review how the immigration system affects our ability to attract world-leading talent and consider the impact of any changes on this. DSIT should explore whether the number and type of visa issued to workers in the quantum sector can be tracked. Further analysis should be undertaken to establish the extent to which upfront visa costs or processing times deter high skilled overseas workers.

## International research exchanges and ATAS

Several Taskforce participants highlighted the positive impact of researcher and student exchanges in supporting knowledge transfer, skills development, and expanding professional networks.

> **Finding:** The UK should continue to seek researcher and student exchanges with other leading quantum nations through relevant bilateral and multilateral arrangements.

The Academic Technology Approval Scheme (ATAS) certification was recognised as necessary by many within the academic community, to help to maintain the security of sensitive research. However, several participants did raise concerns with the length of time taken for certification, and a perceived lack of transparency through the process. The Taskforce understands that the speed of processing ATAS applications has improved over the last 18 months and is now within the timeframe published in the ATAS guidance[footnote 51].

> **Finding:** The timeliness of ATAS decision making should continue to be monitored to ensure that this necessary mechanism to help protect sensitive research is not inhibiting the ability of researchers to collaborate internationally to advance the field.

# Forging new pathways into the sector

This section considers how training and education pathways that are currently underutilised by the quantum sector could be used to meet the diversifying and increasing needs for technicians and engineers in the sector as well as the need for more 'quantum natives' – people who understand these technologies in the wider economy. This is not an exhaustive review of all pathways but focuses on those raised by the Taskforce. Given technical training often requires good industry links with regional suppliers of technical education, it will be important for the quantum industry to engage effectively with these providers as the sector's needs grow in the future to ensure that provision is tailored to meet their needs.

## Apprenticeships and technical education

Apprenticeships should represent an attractive route for organisations in the quantum sector to train or retrain staff for several relevant engineering and technical roles. However, the Taskforce is only aware of a small number of apprenticeships being offered across the sector.

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### Explainer – Apprenticeships

Apprenticeships cover a wide range of qualification levels, from the equivalent of 5 GCSE passes to the equivalent of a master's degree. They are based on a learner being employed, undertaking training on the job, with at least 6 hours a week in a formal training environment. Information on the different levels of apprenticeships is set out below.

| Name | Level | Equivalent educational level | Length |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Intermediate | 2 | 5 GCSE passes | At least 12 months |
| Advanced | 3 | 2 A level passes | 18 to 24 months |
| Higher | 4 and 5 | Foundation degree | 18 months to 5 years |
| Degree | 6 and 7 | Bachelor’s or master’s degree | 3 to 6 years |

Both employers and apprentices have high satisfaction rates of over 80%, with most apprentices staying with their employer.

Apprenticeships are aligned to occupational standards, which are employer-focussed descriptions of an occupation. They show associated duties, knowledge, skills and behaviours alongside the relevant training courses and potential for education progression.

The Taskforce has identified 5 roles that are in high demand across the quantum sector which could be filled through an apprenticeship training pathway. These are:

- Electrical and electronics engineers
- Electrical and electronics technicians
- Mechanical engineers
- Mechanical technicians
- Lab technicians and technician scientists

## Apprenticeship training

Training for these 5 roles could be delivered based on existing apprenticeship standards. These standards focus on developing the core competencies associated with the respective roles.

Evidence from other engineering sectors indicate that using sector-specific standards can risk alienating potential candidates, who may fear that a qualification would not allow them to work in other sectors. Sector-specific apprenticeships may also be more difficult to deliver, as they are likely to require more highly trained specialist training staff and attract fewer students, resulting in courses that are uneconomical for training providers. However, the need for quantum specific apprenticeships should be kept under review as the skills needs of the sector continue to develop and grow.

The delivery model for an apprenticeship typically involves around 80% of training taking place on the job. This gives significant flexibilities to allow for any relevant quantum-specific skills to be developed through workplace learning, or through additional quantum modules which could complement the existing apprenticeship standards.

The Science and Technologies Facilities Council (STFC) and NPL could both play an important role in supporting the development of quantum training modules targeted at apprentices. This is because both bodies are large employers with established apprenticeship programmes and significant quantum workforces. Using this expertise to develop quantum training modules should reduce the burden on smaller employers from having to develop this training individually.

> **Finding:** Apprenticeships are an underutilised route into the sector but generally show high success rates in terms of outcomes for the employer and employee. Taskforce engagement indicates that there is currently no need for quantum specific apprenticeship standards to be developed. This is because the 5 engineering roles identified are unlikely to require significant quantum expertise. But there is appetite for quantum-specific content for those that are interested within existing schemes. Efforts should be made to explore how to make better use of the apprenticeship training routes within the sector.

**Case study – Apprenticeships in NQTP**
STFC have launched a pilot Quantum-enabled Apprenticeship Programme. The programme is based on an advanced engineering technician apprenticeship, with additional training provided to enable the apprentices to work in a quantum-relevant area of STFC.

NPL operates a well-established apprenticeship scheme, which typically includes apprentices being rotated between multiple departments as part of their training. At least 16 apprentices have undertaken rotations within NPL’s quantum-relevant areas, working towards either a laboratory technician or metrology technician apprenticeship.

## Apprenticeships - support for SMEs

This report has highlighted that most companies in the quantum ecosystem are SMEs. DSIT analysis indicates that the typical UK quantum technology company in 2023 is small, with less than 50 employees[footnote 52]. Several engineering sector bodies and think tanks have stressed the obstacles that

SMEs encounter when engaging with apprenticeships[footnote 53]. These obstacles are typically associated with SMEs having very small HR functions, more limited resources, and the complexity of the apprenticeship system. Examples of barriers include difficulty navigating the apprenticeships system and accessing relevant funding, having limited capacity to meet the administrative and supervisory requirements of an apprenticeship, and having less capacity to engage in the process to develop apprenticeship standards.

It will be important that existing support measures for SMEs training an apprentice are clearly articulated to companies in the quantum sector.

> **Finding:** Given the challenges documented around SMEs taking part in apprenticeship programmes more broadly, there is a need to consider what further support could be provided to enable them to invest in apprenticeships. This should look at similar schemes that have operated in different sectors, such as the Advanced Therapies Apprenticeship Community (ATAC).

> **Recommendation 10:** Quantum organisations should invest in apprenticeships where they align with their workforce needs, particularly for the 5 roles identified by the Taskforce. A short quantum module that could be offered to apprentices should be developed (NPL and STFC are well placed to do this in collaboration with industry groups). Support should be provided to help quantum SMEs to navigate the apprenticeship system using existing guidance and consideration given to whether a more coordinated effort is needed tailored to the sector.

## Apprenticeships - awareness

Interest in vocational training routes is currently at high levels amongst both young people and their parents. A recent survey by Enginuity on attitudes to vocational training[footnote 54] indicates that 93% of parents want to learn more about apprenticeship opportunities for their children, while 86% of children aged 11 to 18 would now consider an apprenticeship over a conventional degree.

> **Finding:** It is important to clearly signpost vocational training routes into the quantum sector, as well as academic pathways. This should include the technical career pathways that are currently most relevant to enter and progress within the quantum sector.

> **Recommendation 11:** DSIT should work with relevant partners to develop and publish the technical career pathways relevant to the quantum sector, signposting existing occupational standards and training opportunities.

## T Levels

T Levels were highlighted as a potentially valuable route into an apprenticeship, with relevant T Levels in Science and Engineering & Manufacturing. Industry placements make up an important element of T Levels, but there are currently low numbers of employers offering these placements. Some attendees considered this was due to them being a relatively new qualification which may be caused by a low level of awareness of this training route, the length of the placement, or limited capacity within organisations to take on a 16-to-18-year-old. The Taskforce noted that new resources have been published to help employers develop their technical talent pipeline through industry placements for T Level science students[footnote 55], which could be one potential feeder route for the quantum workforce.

## Continuous Professional Development

Continuous professional development (CPD) can describe a wide range of learning activities that professionals engage in to develop or enhance skills or knowledge. This can range from self-directed learning, through to formal programmes with accredited qualifications.

Within the sector, given it will increasingly rely on skillsets which are present in the wider economy, CPD could be used to introduce people to quantum technologies and its applications, upskill professionals in relevant occupations to join the quantum workforce, as well as to support the development and progression of those already in the quantum sector.

**Explainer - Current CPD landscape**
There are already a broad range of quantum-relevant learning and training resources available, including self-paced and tutor-led courses:

**Self-paced courses:** These typically allow users to learn flexibly by working through curated, interactive online resources. They do not typically involve any tutor supervision.

Q-CTRL's Black Opal is an example of a course that focusses on key concepts in quantum computing, and is included as part of NQCC's SparQ user engagement programme. QURECA offers CPD certified online courses for the general public and industry. IBM Quantum Learning is another example of a self-paced online course focused on quantum computing, with resources available through Qiskit. Other platforms, such as Brilliant, focus on many of the elements of foundational knowledge relevant to quantum technologies.

**Tutor-led courses:** There are many online courses available from universities, either directly or through online platforms such as Coursera or FutureLearn. They vary significantly in areas of focus, the level of assessment, and the amount of academic supervision and support. Examples of these courses include UCL's 'Introduction to Quantum Computing', and the joint NQCC/Bristol courses 'Introduction to Quantum Information Science & Technologies' and 'Quantum Computation'.

**Workshops, seminars and events:** Alongside there are a range of short workshops, conferences, and other events relevant to the quantum ecosystem that support development. These include events like the NQCC Hackathon, and workshops provided by relevant professional societies for their members.

The Taskforce has set out how the growth of the sector will be reliant on attracting a broad range of engineers and technicians, and that the level of quantum knowledge required will vary significantly for these roles. CPD could play an important part in supporting existing engineers and technicians to transition into the quantum workforce, particularly where these roles require an awareness or understanding of quantum physics. It should also play a vital role in upskilling a broader range of workers to adopt quantum technologies. Creating these upskilling opportunities will be particularly important, as over 80% of the UK's 2030 workforce have already left formal education[footnote 56].

For CPD to provide these routes into the quantum sector, some barriers must be overcome. These include the awareness of quantum CPD opportunities amongst relevant engineers and technicians, and the focus of CPD courses. Many existing CPD opportunities are focussed around introducing quantum technologies to a broad audience. While these courses are necessary to support the growth of the quantum workforce, the Taskforce has found that more tailored courses are also required.

There is a need for tailored courses to focus on the quantum skills and knowledge required to upskill those with relevant professional backgrounds to undertake specific roles within the quantum sector. Currently there is no common understanding of these skills, which vary significantly according to the role, and limited training provision to meet this need. This is placing the burden of training onto quantum companies to develop and deliver this training as part of their internal induction. Delivering this training may be acting as a barrier to accessing skills, particularly for SMEs who are likely to have limited resources.

Recommendations 1, 2 and 3 of this report, set out in the skills needs section, will be vital to support the development of these more targeted training courses, and to understand the level of demand for such courses. Once skills mapping activities have been undertaken, this information should be published to increase awareness amongst training providers and potential course participants.

CPD will also continue to be vital for those in quantum specialist roles at the cutting edge of research and development. Knowledge exchange activities such as conferences, peer-reviewed journals, and partnerships between industry and academia currently provides an effective mechanism to share rapidly developing specialist knowledge and skills. These activities should continue to be supported by the sector.

Policymakers and regulators could be introduced to the capabilities, applications, and limitations of quantum technologies through CPD courses. While not an area of focus for the Taskforce, CPD targeted at those in the public sector enable public bodies to be an intelligent first customer of quantum products and services. The Taskforce agrees with the Regulatory Horizon Council's findings that such training for regulators should support the development and acceptance of proportionate, timely, and adaptive regulatory systems[footnote 57]. The Government Office for Science's STEM Futures programme could be used to support this exchange of knowledge into regulators and the public sector.

> **Finding:** CPD courses could play an important role in upskilling those with relevant professional backgrounds to join the quantum sector, but there is a lack of clarity over the requirements for future provision. It is anticipated that the market will be able to respond to increasing demand for CPD courses, but clear signals on the skills required and the demand for these courses will be required. Wider reforms to the post-16 skills system are currently planned, government should consider how these reforms could help meet the needs of the quantum sector to access CPD.

## Undergraduate and master's programmes

There is an increasing demand within the quantum sector for roles that could be undertaken by a candidate with an undergraduate or master's level STEM education. As the need for these roles continues to grow, it will be increasingly important for relevant degree programmes to both teach the skills needed within the sector and provide an awareness of opportunities in quantum.

The Taskforce has used the range or roles identified through our skills needs workshops to define the degree pathways that are most relevant to quantum technologies at undergraduate and master's level. These degree pathways are:

- Physics
- Electrical engineering
- Mechanical engineering
- Computer science
- Mathematics
- Materials science
- Chemistry

## Physics

Most quantum research programmes have historically sat within university physics departments. This has resulted in the majority of quantum technologies content aimed at undergraduate and master's level students focussing on physics courses. These long-standing links have nurtured a high level of awareness and interest in quantum technologies from current and prospective physics students. The Taskforce has heard anecdotally from leading universities that modules on quantum technologies are now amongst the most popular optional modules for physics students.

The Taskforce has found that those studying physics, applied physics, or quantum physics at a graduate or undergraduate level would likely be well placed to pursue several roles within the sector. These are typically physical engineering roles that require knowledge or understanding of quantum physics, with examples including engineers working on photonics, packaging, cryogenic systems, nanofabrication, systems integration, and application development.

Quantum now features on every physics BSc course, and the UK now has at least 8 dedicated quantum master's programmes. This makes the UK home to the second highest number of quantum master's programmes in the world[footnote 58], behind only the US, with courses growing organically in response to increased demand. These quantum physics programmes have a mix of approaches, with some courses giving a broad overview of quantum technologies and their applications, while others focus on specific areas. Clear routes exist for the accreditation of these physics courses, with the Institute of Physics accrediting 95% of all physics degrees[footnote 59].

There was a consensus amongst stakeholders that these physics master's programmes are effective at providing the knowledge required to go on to undertake a PhD in quantum. However, there was a perception that these courses are not sufficiently tailored to meet the skills needs of industry. Companies involved in the Taskforce working group have highlighted that recent graduates of these courses often require additional in-house training, creating a potential barrier to accessing skills. Anecdotally, there were also concerns highlighted to the Taskforce that too few physics graduates had sufficient experimental skills.

> **Finding:** There is a need for quantum MSc programmes that are more focused on providing the skills needed by industry, and for greater engagement between industry and academia in the development of these courses. It is important that this engagement takes a form that is not overly onerous on businesses or universities and minimises duplication, particularly as the number of courses offered is highly likely to increase in response to growing demand.

The skills mapping and skills survey recommended by the Taskforce should build a common understanding on skills that are most in demand across the sector and help to inform the development of courses. Lessons could also be learned from international schemes, such as Mitacs in Canada[footnote 60].

## Engineering, computer science, mathematics and chemistry

There are a small but increasing number of instances where quantum technologies are being included as examples or case studies in degree programmes outside of physics. Specific examples of this were highlighted to the Taskforce in electrical engineering, computer science and chemistry degrees.

The inclusion of quantum case studies is not sufficient to provide the skills required to work in the sector, but it is likely to increase awareness of quantum technologies for students that may not otherwise encounter quantum. Raising this awareness will be increasingly valuable to attract a diverse range of talent to the quantum sector. The availability of resources and lesson plans is likely to be a barrier to the uptake of quantum examples across a broader range of degree pathways. Those delivering lectures in relevant subjects may not have the time or expertise to develop these resources themselves.

> **Finding:** As demand for skills within the quantum sector continues to grow, there will likely be a need for quantum-specific modules and case studies to be included within some undergraduate courses. The skills mapping activities recommended by the Taskforce should help to identify a comprehensive list of areas where quantum modules are required. This issue is considered further in the outreach section.

> **Finding:** The accreditation of master's programmes can be important in validating the quality of a course to potential students, and ensuring the qualification can be recognised by professional bodies. While there is clarity on the accrediting body for physics-based qualifications, there is no agreement on the appropriate bodies to accredit quantum qualifications that sit outside of physics programmes. This will also be important for the accreditation and recognition of CPD courses.

> **Recommendation 12:** DSIT should engage with the Engineering Council, the regulatory body for the UK engineering profession, to establish which bodies are best placed to accredit quantum engineering degrees and master's programmes. Universities should engage with industry to help to ensure that master's courses are designed to equip students to enter academia or industry.

## Industry placements

There has been a recent increase in the number of quantum companies offering internships to help attract a broader range of talent. Companies offering these internships have highlighted that there are challenges reaching a broader range of students, with interns typically coming from a physics background with pre-existing exposure to quantum technologies.

The Taskforce considered the SPIN scheme which has been developed for the space sector and felt there are valuable lessons that could be learnt from this and other schemes when considering whether to design a quantum specific scheme for the sector in the future.

**Case study – Space Placements in Industry**
The Space Placements in Industry (SPIN) scheme provides placement opportunities for those considering employment in the space sector and connects space sector organisations who want to find the most talented and enthusiastic people to ensure the future success of their businesses.

The scheme is managed by the UK Space Agency and supported by the Satellite Applications Catapult. It allows undergraduate, master's and PhD students to apply for an eight-week paid placement in the space industry. The students have a contract of employment with a salary at the National Living Wage. Typically, one student placement is funded by the government for each industry partner, although these partners can take more than one student and cover the costs themselves.

The SPIN programme is considered successful in attracting candidates to the space sector and developing the skills and experience of students. There have been over 500 student placements through SPIN over the last 10 years, with over one third of interns going on to employment within the sector. The scheme has recently been expanded, with approximately 130 placements due to take place in 2024.

A visible, nationwide scheme could be a valuable route for attracting talented candidates to the quantum sector. It could be particularly effective for targeting those studying engineering and computer science subjects, who may not otherwise be aware of career opportunities within the quantum sector.

> **Finding:** Industry placements offer valuable opportunities for interns to gain new skills and a better understanding of working in the quantum sector. These placements should be encouraged and further explored by the community.

> **Recommendation 13:** DSIT should explore the merits of establishing an industry placement scheme for the quantum sector.

# Promoting career opportunities in quantum

Making sure that the future workforce is quantum-literate and has the skills to meet the needs of the sector starts with ensuring that school-aged children have the skills they need to thrive within the sector and to adopt these technologies elsewhere when they grow up.

Following discussions with relevant professional associations (RS, RAEng, IoP and the BCS), there was consensus amongst the working group that ensuring the STEM curriculum is taught effectively is the most impactful activity required to build the foundations for the future quantum workforce in terms of school education. There are many existing challenges around the current provision of STEM education which are being considered as part of the current curriculum review, and a variety of suggested changes to the STEM curriculum and its provision which are likely to benefit many sectors including quantum. Ensuring that STEM subjects are taught effectively by suitably trained teachers is a key component of this wider provision[footnote 61][footnote 62][footnote 63].

The Taskforce has determined that at GCSE and below, there are no quantum specific requirements that need reflecting within the curriculum to help prepare students, and few if any changes required at A-level for physics or maths[footnote 64]. For engineering and computer science it is too early to say and there is a need to bring the communities together to consider this further.

These suggestions have been fed into the curriculum review. As these are not quantum-specific we have not covered them in any depth here.

> **Finding:** Ensuring that the wider STEM curriculum is appropriate and being delivered effectively in schools is crucial to building the foundational skills needed for the quantum sector and many others and will have the biggest impact on the skills acquired by school-aged children who may enter the future quantum workforce. Professional bodies should continue to explore if any changes will need to be made to the curriculum in the future recognising there is a high bar.

However, this doesn’t mean there isn’t work to do to inspire and educate the next generation to encourage them to choose a career in the quantum sector as well as to create a quantum-literate workforce able to benefit from the application of these technologies.

## Schools Outreach

It should be recognised that sustained, early, multi-contact outreach activities can be incredibly impactful, in terms of their reach across the population, and their ability to inspire, particularly amongst more underrepresented groups if designed in the right way[footnote 65][footnote 66][footnote 67].

There was consensus amongst the schools working group about the value of creating quantum-specific outreach material to start to introduce pupils to key concepts and real-life case studies to both inspire and build understanding. For example, key concepts around how quantum computing is different from classical computing could be introduced through experiential learning as opposed to curriculum changes. There are impactful initiatives both in the UK[footnote 68][footnote 69][footnote 70][footnote 71] and internationally which have taken this approach and which we can learn from[footnote 72][footnote 73].

There is already a large volume of outreach activity available to schools. The Taskforce has seen some examples which have shown impressive results in terms of inspiring the next generation of scientists and engineers to take up STEM subjects. These programmes could provide a useful platform for quantum-specific material and case studies, as well as lessons learnt.

It is important that such interventions are designed in a way that makes them accessible and impactful for all students including those underrepresented in the industry. They also need to be designed in such a way as to encourage practical experiments and applied learning which we know students are doing less of, but which are particularly good at engaging those underrepresented in the sector[footnote 74].

> **Finding:** Outreach activities with quantum learning outcomes could help inspire the next generation of scientists and engineers but they are better delivered through successful pre-existing long-running STEM schemes where possible. These need to be accessible by all students, not just those who already have a strong science focus, given the patchy provision of existing schemes at present amongst underrepresented groups.

There is good evidence of successful outreach schemes that could act as a vehicle for such content. Existing successful schemes include Neon Futures, an established searchable platform for teachers and career leaders to find quality STEM career outreach activities and experiences, or the STEM ambassador scheme.

## Wider outreach

Outreach is also important for those in the existing workforce who might be interested in joining the sector in the future. The specific requirements for such outreach and awareness raising activities will vary depending on the target groups and should be designed according to the identified need from the skills mapping work in the recommendation 1 and 2 of this report.

> **Finding:** Outreach will also play an important role in attracting people already in the wider UK workforce and will need to be tailored to their specific needs.

There are already well-established principles for good outreach which should be used to design such activities:

- **Accessible:** easily accessible by all interested parties.
- **Relevant:** Relating examples to the real world, with contextualisation and historical context.
- **Inclusive:** Should ensure all have opportunities to engage in activities that inspire engineering and technology futures, and that no one is left behind.
- **Evidence-based:** Evaluate all activities, learn what works, iterate and share.

**Case study - Quantum City**

Quantum City is a multi-partner public engagement initiative initiated in 2018 by the Quantum Technology Hubs supported by the National Physical Laboratory. Born through a desire to build on the positive findings of the 2017 EPSRC-commissioned public dialogue in quantum technologies[footnote 75] through a coordinated approach, Quantum City's aim has been to promote understanding of the potential of quantum technologies in line with the aims of the National Quantum Technologies Programme, showcase the UK's expertise in this area, and inspire young audiences to become the next generation of quantum technologists.

Engagement takes place primarily through participation in science festivals; classroom resources and online school assemblies focusing on quantum career pathways; a dynamic, interactive website (https://www.quantumcity.org.uk/); and partnerships with international organisations to support similar activities abroad.

To date, Quantum City partners have engaged with over 20,000 visitors at outreach events; disseminated posters of the benefits of quantum technology to over 1350 schools across the UK; produced career factsheets highlighting the diverse career pathways in the sector; and interacted with hundreds of school children through online webinars. Throughout, the feedback has been overwhelmingly positive.

In 2025, the future of Quantum City was secured for a further 4 years, with EPSRC funding to the new Quantum Technology Hubs to promote skills enhancing activities. Cross-Hub agreement was reached for resources to be invested in:

- Profile raising, expansion and diversification of Quantum City and attracting new audiences.
- Highlighting the contributions of technicians.
- Training early career researchers/PhD students in science communication.
- Continuing to promote careers options in quantum.

**Recommendation 14:** DSIT should work with NQTP partners and the wider community to agree priorities and routes to develop both educational and promotional outreach material, building on existing efforts. This should aim to raise awareness of the opportunities within the sector, across the economy as a whole and to provide additional learning opportunities within school-aged children, adhering to the best practice principles set out above.

Work under recommendation should include:

- Mapping and evaluating existing outreach and awareness raising activities for schools and feeder sectors and the wider public.
- Developing and accrediting quantum specific learning material for students and teachers, using trusted existing schemes to share resources with schools.
- Making sure age and profession appropriate careers content available for schools, universities and the public which highlights the diverse range of roles available in the quantum sector.

**Case study – NQCC outreach and education**
The NQCC delivers a range of outreach and education activities to enhance quantum skills in the UK and public understanding of quantum computing. These activities are shaped by an Outreach and Public Engagement strategy that defines objectives for the NQCC’s public engagement, best practices, evaluation methods, widening participation, and a model for delivery.

To date, NQCC staff have directly engaged with over 3,000 members of the general public and over 1,500 school students and teachers. This includes various activities, such as the NQCC's pop-up exhibit, public talks, careers fairs, careers talks, continuing professional development (CPD) talks for teachers, and an annual summer school delivered in collaboration with the University of Oxford. The majority of these activities utilise existing public engagement and education initiatives with established audiences to help increase awareness of the NQCC's programme and introduce quantum computing topics to the public. The success of these activities reveals a high level of interest in understanding quantum computing and its applications across the wider public.

# Collaboration

The work of the Taskforce has built upon existing fruitful collaborations between industry, academia, national laboratories, learned societies, trade and professional associations, and government departments.

Insights from these groups have been invaluable to the Taskforce's work which has engaged with over 150 representatives from across the sector through over 25 workshops and working group meetings over 12 months. While the work of the Taskforce is ending with the publication of this report, there is a clear need for continued efforts to bring the community together to consider future skills needs, to share best practice, coordinate efforts where this is needed and help to shape policies around future provision.

Special interest groups that consider quantum skills should continue to serve their individual communities, but it is helpful to represent one community view to educators and policymakers on key issues. This should include representation from the key groups across the community that are developing skills interventions or that need them, such as RAEng, IET, IoP, Royal Society, UKQuantum, TechUK, the Photonics Leadership Group, the 5 quantum hubs, BCS, NQCC and UKRI.

As we have highlighted throughout this report, the quantum sector is small but strategically important to the UK. The sector is expected to continue growing rapidly, with the skills needed in the sector diversifying further. It will be vital to ensure that these growing and changing skills needs continue to be understood across the sector and appropriate actions are being taken collectively to address any needs identified.

> **Finding:** There is a need for continued efforts to share information and coordinate skills activities across the landscape. Such information sharing should support the development and delivery of future skills interventions.

At the governmental level, no one department is responsible for quantum skills programmes. Many elements of the skills and education system are devolved across the UK. This involves responsibilities for education and training being devolved to the respective legislatures of Scotland, Wales and Northern Ireland and their associated governments[footnote 76].

> **Finding:** It will be important for the 4 governments of the UK to continue to share information on quantum skills needs, and evidence on the effectiveness of respective skills interventions. Demand and supply for these important STEM roles should be considered at an aggregate level across the economy through the work of Skills England and relevant authorities within the devolved administrations. Where necessary, governments should work together to improve access to these skills.

> **Recommendation 15:** Government, working with the devolved administrations, should establish a Quantum Skills Forum to meet with relevant trade associations, professional societies, and representatives from academia to share information on quantum skills needs, coordinate activities, identify gaps in training provision and discuss how these can be addressed across members.

The Forum's deliberations should be reported back to the NQTP's Strategic Advisory Board (SAB) which provides challenge and strategic advice to government and UKRI to inform policy and delivery, including on skills, as well as the Quantum Strategy Implementation Board, a cross Whitehall group of officials responsible for overseeing the strategy's implementation.

Making progress on the areas identified in this report will require sustained commitment, work and collaboration from organisations across the sector.

> **Recommendation 16:** The Office for Quantum in DSIT should develop and coordinate a programme of work to take forward the findings and recommendations made by the Taskforce and report on progress to the SAB and Quantum Strategy Implementation Board.

Many of the physics, engineering, technical, and digital skills needed within the quantum sector are also in high demand across several other technologies, sectors and industries with evidence of some persistent skills shortages. Examples of these sectors include, but are not limited to, semiconductors, photonics, space, artificial intelligence, automotive, advanced manufacturing, nuclear, and net zero.

Within the UK government several departments and agencies have an interest in the development of these skills. To support the government's wider policy ambitions, it will be vital to increase the supply of these STEM skills across the economy, so that all critical technologies and priority sectors are able to access the skills needed to support growth

> **Finding:** Demand and supply for important STEM roles should be considered at an aggregate level across the economy through the work of Skills England. Where necessary, government should work together to improve access to these skills.

# Findings and Recommendations

This section sets out all findings and recommendations from across the Quantum Skills Taskforce report, split by chapter.

## Skills needs of the sector

### Findings:

- There will continue to be a need for quantum expertise grounded in physics and mathematics to support the growth of the sector, at least in the near and mid-term. Quantum specialists make up a significant proportion of the workforce and demand for their skills will continue to grow as the sector does. The UK will rely on both international and domestically trained talent to meet the demand for these roles.
- The demand for engineering and technical skills will grow in scale in the future across a broad range of engineering disciplines. Most of these roles will not require deep expertise in quantum physics but will require some form of quantum training. This could take place through on-the-job training, through short courses, or as part of degree programmes. To support the development of more targeted training courses and increase awareness of opportunities for engineers and technicians within the sector, there is a need to understand role specific requirements in greater detail.

- It is important that demand for engineering roles in the quantum sector is considered as part of a broader, economy wide assessment of engineering skills needs.
- Skills for the adoption of quantum computing are an important component of future demand. There is a need to ensure that we better understand the skills needed to adopt quantum computing across the economy. We must also consider the training pathways that could be used to upskill existing workers in the industries that are most likely to benefit from the adoption of quantum computing.
- Having a diverse workforce representative of the UK's wider population has been and will continue to be a challenge for the sector, but is vital to its future success and realising the full potential of these technologies.
- There is a need to continue monitoring the skills needs of the sector as these develop, and to explore opportunities to improve the data held on the workforce.

**Recommendations:**

- Recommendation 1: DSIT should work with the relevant learned and professional societies and engineering bodies to identify and map the specific quantum skills and knowledge that are required by different engineering disciplines to work within the quantum sector, as well as the pathways into the sector.
- Recommendation 2: The National Quantum Computing Centre (NQCC) should expand their flagship SparQ user engagement programme and map the skills needed to adopt quantum computing in priority industries. This should consider how these relate to existing digital skills and the most appropriate training pathways.
- Recommendation 3: Across the range of activities within the quantum programme, and the community as a whole, to train and recruit talent, efforts should be made to ensure they are designed to enable and encourage participation by a diverse range of people. The community should be encouraged to collect diversity data.
- Recommendation 4: DSIT should work with relevant trade associations, learned societies, and research councils to run a regular skills survey. This should maintain an up-to-date understanding of the skills needs across the sector, the workforce challenges experienced by both industry and academia and improve information on the workforce. DSIT should also continue to explore other opportunities to develop and access robust data on the quantum workforce. This work should complement Skills England's unified assessment of skills needs, and other skills mapping being undertaken across government.

## Building on our strengths in quantum

### Findings:

- CDTs and DTPs both offer attractive packages for PhD studentships. There are benefits to students around cohort-based training at PhD level and appetite from SMEs to co-fund PhD places but perceived barriers to them doing so at a system and university level. The Taskforce welcomes the introduction of UKRI's new deal for postgraduate research, which is likely to provide additional opportunities for complementary training.
- There is a need to better understand PhD-level skills provision across the quantum programme and whether it is addressing identified gaps in skills.
- There is a need to better understand the composition of the academic workforce in the UK to inform any future activity designed to ensure it remains competitive. It would be beneficial to articulate the opportunities and benefits of the UK ecosystem. The workforce needs of academia should be monitored as part of the skills survey proposed in recommendation 4 of this report, and further HESA analysis would be beneficial on the academic workforce.
- The Taskforce endorses the Royal Society report on research careers and commends it to university leaders looking to retain future leaders.
- Future fellowship schemes should be based on these examples of good practice, accessible to academia and industry and should not be overly prescriptive in their focus. They should generally be used to support research excellence or curiosity-led research as the primary driver, and should not be directed exclusively at applied research, as there are opportunities to pursue applied research in other areas of the NQTP. Some fellowships allow greater flexibility on the activities, equipment and support staff that can be funded, which typically make them more attractive to senior researchers.
- Community building activities are also important for early career fellows.
- Stakeholder feedback indicates there is a potentially acute shortage of technicians in academia. It will be important to monitor whether existing initiatives such as UKITSS and the Technician Commitment are having the desired effect and to consider if specific actions are required in institutions undertaking quantum research.
- While the skills needs of the sector are diversifying, the Taskforce finds that efforts to attract international talent should focus on quantum specialist roles at this time. This is due to the long time required to develop these skills domestically, and their relatively limited availability. The specific specialist roles targeted should be kept under review, guided by the results of the regular skills survey. There are also benefits from

focussing efforts on a wider geographic pool, such as accessing a larger pool of potential talent. As time goes by it may be necessary to refocus efforts towards attracting wider skills in engineering to scale for example.

- It will be important to promote the broader benefits and attractiveness of life in the UK to further support the attraction of future quantum leaders. It will also be important to better showcase the strength of the UK quantum ecosystem and the exciting career opportunities within it.
- Analysis currently available does not demonstrate a link between upfront immigration costs and the level of migration, although we have heard some anecdotal accounts that high upfront immigration costs act as a barrier to retaining and attracting overseas talent. We heard accounts of challenges around the time it takes to secure a visa, however visa processing times are favourable when compared to the UK's global competitors, with visas consistently processed within those published service level agreements. It's important to keep under review how the immigration system affects our ability to attract world-leading talent and consider the impact of any changes on this. DSIT should explore whether the number and type of visa issued to workers in the quantum sector can be tracked. Further analysis should be undertaken to establish the extent to which upfront visa costs or processing times deter high skilled overseas workers.
- The UK should continue to seek researcher and student exchanges with other leading quantum nations through relevant bilateral and multilateral arrangements.
- The timeliness of ATAS decision making should continue to be monitored to ensure that this necessary mechanism to help protect sensitive research is not inhibiting the ability of researchers to collaborate internationally to advance the field.

**Recommendations:**

- Recommendation 5: UKRI should consider opportunities and mechanisms for industry co-funding as part of UKRI PhD programmes, and how these could be made more visible to industry and accessible to SMEs. The impact of existing co-funding requirements should be reviewed to ensure they are not inadvertently limiting the level of industry investment that universities can attract. Universities should consider how they could make industry more aware of co-funding opportunities.
- Recommendation 6: A landscape review of publicly funded PhD-level quantum skills activities should be published, alongside a gap analysis on the fellowship programmes relevant to the quantum sector.
- Recommendation 7: Providers, including EPSRC, should explore whether there is value in more community building activities to support the broader development of early career fellows.

- Recommendation 8: There is a need to ensure that quantum is a great place to work for technicians in research. Relevant academic departments should continue to follow the recommendations identified by the UK ITSS, TALENT Commission and the Technician Commitment to support the quantum technician workforce. DSIT and UKRI should support those universities to adopt these recommendations and share good practice on their implementation.
- Recommendation 9: Government efforts to attract international talent should focus on the 'quantum specialist' roles for which there are domestic skills shortages. These efforts should have a wider geographic focus beyond the US and India, including countries that have developing academic capabilities but do not yet have a commercial quantum industry. They should also provide additional information on the attractiveness and benefits of life in the UK, alongside further information on the strength and dynamism of the UK quantum sector.

## Forging new pathways into the sector

### Findings:

- Apprenticeships are an underutilised route into the sector but generally show high success rates in terms of outcomes for the employer and employee. Taskforce engagement indicates that there is currently no need for quantum specific apprenticeship standards to be developed. This is because the 5 engineering roles identified are unlikely to require significant quantum expertise. But there is appetite for quantum-specific content for those that are interested within existing schemes. Efforts should be made to explore how to make better use of the apprenticeship training routes within the sector.
- Given the challenges documented around SMEs taking part in apprenticeship programmes more broadly, there is a need to consider what further support could be provided to enable them to invest in apprenticeships. This should look at similar schemes that have operated in different sectors, such as the Advanced Therapies Apprenticeship Community (ATAC).
- It is important to clearly signpost vocational training routes into the quantum sector, as well as academic pathways. This should include the technical career pathways that are currently most relevant to enter and progress within the quantum sector.
- CPD courses could play an important role in upskilling those with relevant professional backgrounds to join the quantum sector, but there is a lack of clarity over the requirements for future provision. It is anticipated that the market will be able to respond to increasing demand for CPD courses, but clear signals on the skills required and the demand for these courses

will be required. Wider reforms to the post-16 skills system are currently planned, government should consider how these reforms could help meet the needs of the quantum sector to access CPD.

- There is a need for quantum MSc programmes that are more focused on providing the skills needed by industry, and for greater engagement between industry and academia in the development of these courses. It is important that this engagement takes a form that is not overly onerous on businesses or universities and minimises duplication, particularly as the number of courses offered is highly likely to increase in response to growing demand.
- As demand for skills within the quantum sector continues to grow, there will likely be a need for quantum-specific modules and case studies to be included within some undergraduate courses. The skills mapping activities recommended by the Taskforce should help to identify a comprehensive list of areas where quantum modules are required. This issue is considered further in the outreach section.
- The accreditation of master's programmes can be important in validating the quality of a course to potential students, and ensuring the qualification can be recognised by professional bodies. While there is clarity on the accrediting body for physics-based qualifications, there is no agreement on the appropriate bodies to accredit quantum qualifications that sit outside of physics programmes. This will also be important for the accreditation and recognition of CPD courses.
- Industry placements offer valuable opportunities for interns to gain new skills and a better understanding of working in the quantum sector. These placements should be encouraged and further explored by the community.

**Recommendations:**

- Recommendation 10: Quantum organisations should invest in apprenticeships where they align with their workforce needs, particularly for the 5 roles identified by the Taskforce. A short quantum module that could be offered to apprentices should be developed (NPL and STFC are well placed to do this in collaboration with industry groups). Support should be provided to help quantum SMEs to navigate the apprenticeship system using existing guidance and consideration given to whether a more coordinated effort is needed tailored to the sector.
- Recommendation 11: DSIT should work with relevant partners to develop and publish the technical career pathways relevant to the quantum sector, signposting existing occupational standards and training opportunities.
- Recommendation 12: DSIT should engage with the Engineering Council, the regulatory body for the UK engineering profession, to establish which bodies are best placed to accredit quantum engineering degrees and master's programmes. Universities should engage with industry to help to

ensure that master’s courses are designed to equip students to enter academia or industry.

- Recommendation 13: DSIT should explore the merits of establishing an industry placement scheme for the quantum sector.

## Promoting career opportunities in quantum

**Findings:**

- Ensuring that the wider STEM curriculum is appropriate and being delivered effectively in schools is crucial to building the foundational skills needed for the quantum sector and many others and will have the biggest impact on the skills acquired by school-aged children who may enter the future quantum workforce. Professional bodies should continue to explore if any changes will need to be made to the curriculum in the future recognising there is a high bar.
- Outreach activities with quantum learning outcomes could help inspire the next generation of scientists and engineers but they are better delivered through successful pre-existing long-running STEM schemes where possible. These need to be accessible by all students, not just those who already have a strong science focus, given the patchy provision of existing schemes at present amongst underrepresented groups.
- Outreach will also play an important role in attracting people already in the wider UK workforce and will need to be tailored to their specific needs.

**Recommendations:**

- Recommendation 14: DSIT should work with NQTP partners and the wider community to agree priorities and routes to develop both educational and promotional outreach material, building on existing efforts. This should aim to raise awareness of the opportunities within the sector, across the economy as a whole and to provide additional learning opportunities within school-aged children, adhering to the best practice principles set out above.

## Collaboration

**Findings:**

- There is a need for continued efforts to share information and coordinate skills activities across the landscape. Such information sharing should support the development and delivery of future skills interventions.
- It will be important for the 4 governments of the UK to continue to share information on quantum skills needs, and evidence on the effectiveness of respective skills interventions. Demand and supply for these important STEM roles should be considered at an aggregate level across the economy through the work of Skills England and relevant authorities within the devolved administrations. Where necessary, governments should work together to improve access to these skills.
- Demand and supply for important STEM roles should be considered at an aggregate level across the economy through the work of Skills England. Where necessary, government should work together to improve access to these skills.

**Recommendations:**

- Recommendation 15: Government, working with the devolved administrations, should establish a Quantum Skills Forum to meet with relevant trade associations, professional societies, and representatives from academia to share information on quantum skills needs, coordinate activities, identify gaps in training provision and discuss how these can be addressed across members.
- Recommendation 16: The Office for Quantum in DSIT should develop and coordinate a programme of work to take forward the findings and recommendations made by the Taskforce and report on progress to the SAB and Quantum Strategy Implementation Board.

# Annexes

# Quantum Skills Taskforce Terms of Reference

### Background

The National Quantum Strategy set out an ambitious ten-year vision for the UK to be a leading quantum-enabled economy. This would see the UK building on scientific excellence to create a thriving quantum sector, where quantum technologies drive economic growth while contributing to a strong and resilient society. Access to the appropriate talent and skills are vital to achieving this vision.

Securing these skills will be a key challenge of the next ten years. The global demand for quantum skills have grown dramatically over recent years; this demand is likely to grow further with increased public and private investment. There is clear evidence the skills needed by the sector are also diversifying, with a greater demand for engineers and technicians.

Meeting this challenge effectively will require joint working between industry, academia, learned societies, and government. The role of the Quantum Skills Taskforce is to facilitate this cooperation.

**Purpose and Objectives**

The purpose of the Quantum Skills Taskforce is to help ensure that the UK has the workforce needed to develop and adopt quantum technologies. The objectives of the Taskforce are to:

- Develop a shared understanding of the current and future skills needs of the UK quantum sector.
- Identify barriers and risks that could impede the growth of the UK quantum workforce.
- Support the development of proposals to address skills gaps, and barriers to the growth of the workforce.
- Increase awareness of existing skills programmes, supporting the quantum sector to participate in these initiatives, and driving investment in skills.

**Outputs and Deliverables**

The Taskforce will produce a report summarising their findings. DSIT will use the report to inform priority actions for the quantum sector, and to guide future government investments and policy interventions relating to quantum skills.

**Taskforce Membership and Structure**

The Taskforce will be a strategic body, consisting of senior representatives from industry bodies, learned societies, and government departments. The Taskforce will be chaired by Professor Sheila Rowan CBE FRS FRSE FInstP, with a secretariat from the Office for Quantum in DSIT. Proposed members of the Taskforce includes:

- Tom Newby Head of the Office for Quantum, Department for Science, Innovation and Technology

- Stephen Wan, Deputy Director, Skills Strategy and Delivery, Department for Education
- Kathryn Heaphy Deputy Director, Technology, Department for Business and Trade
- Dr Kedar Pandya Executive Director, Strategy Directorate, EPSRC, UK Research and Innovation
- Louis Barson Director of Science Innovation and Skills, Institute of Physics
- Dr Rhys Morgan Director of Engineering and Education, Royal Academy of Engineering
- Dr Araceli Venegas-Gomez CEO QURECA, and Chair of the UKQuantum Skills Group
- Sue Daley, Director, Tech and Innovation, techUK

To ensure that the Taskforce can consider issues at an appropriate level of detail, it will adopt a working group structure based around 5 thematic areas. These areas have been identified as priority themes by DSIT, based on feedback collected in the development of the National Quantum Strategy. These areas are:

- Working Group 1: Apprenticeships and technical education, accredited short courses and CPD
- Working Group 2: Quantum on undergraduate programmes and master's degrees
- Working Group 3: Researcher skills, PhDs, fellowships, the academic workforce, industry experience and entrepreneurial skills
- Working Group 4: International recruitment and retention
- Working Group 5: Quantum in schools and outreach activities

Each working group will consider how diversity can be improved across their respective areas. The working groups will also consider sources of data that could be used to establish targets, monitor progress, and evaluate the effectiveness of interventions. Organisations focused on improving the diversity of the broader STEM workforce will be invited to contribute to each of the working groups.

The working groups will each have up to 15 members, drawn from industry, academia, learned societies, and relevant government bodies. To facilitate informed discussion, membership of these groups will be aimed at individuals that are:

- developing or delivering educational programmes relevant to quantum;
- involved in recruiting or managing quantum-related staff;

- designing policy programmes that will impact on quantum skills; or
- involved in initiatives to improve diversity within the quantum sector.

Appropriate membership of the groups will be sought, with the Taskforce approving the membership of each group. The Taskforce will ensure that these groups are made up of representatives from a broad and representative range of organisations from across the quantum ecosystem. The Taskforce will agree a chair for each of the 4 working groups.

Membership of the Taskforce and the working groups will be voluntary.

**Governance**

The Taskforce will report to the Quantum Strategy Implementation Board (QSIB). It will work with both the Quantum Technologies Strategic Advisory Board (SAB) and National Quantum Technologies Programme Board (NQTP PB), keeping these boards updated and inviting contributions and challenge where appropriate.

**Scope** The Taskforce will focus on the academic, engineering, and technical skills required to develop and adopt quantum technologies in the UK. The Taskforce should not focus on measures to address shortages within the broader STEM workforce.

While the Taskforce is welcome to identify where the quantum sector is reliant on skills in adjacent sectors (semiconductors, for example), it should not focus on interventions to address these gaps.

# Taskforce Working Group Membership

The Taskforce has been supported by 5 thematic working groups.

There are around 85 participants within the working group structure:

- Industry representatives make up 33% of attendees. Amongst industry representatives there has been an effort to engage with companies of different sizes, focused on different areas of quantum technologies, and different elements of development and adoption of quantum.
- Academia representatives make up 23% of attendees. Representatives have been sought from institutions that have been heavily involved in the NQTP skills initiatives, alongside those which receive less skills funding through NQTP. Institutions from England, Scotland and Northern Ireland are represented within the group.

- Learned and professional societies make 19% of attendees, with the rest made up from the public sector (16%) and national laboratories (9%).

# Taskforce Evidence Annex: HESA Student Data

This annex sets out in detail the results of analysis of data from the Higher Education Statistics Agency (HESA) on students studying quantum courses in the UK, as referred to in the main report. Notes on methodology are also provided.

## Headline findings

- There has been a steady increase in the number of postgraduate taught students in quantum, a slower growth in the number of postgraduate research students and a broadly flat profile among undergraduates. In 2021/22, there were 105 postgraduate taught students, 75 postgraduate research students and 15 undergraduate students enrolled on a course with “quantum” in the course title.
- The age profile of quantum students was markedly different to the profiles of related student cohorts. Over 2019/20 to 2021/22, 82 per cent of quantum course entrants were aged between 21-24; this compares to 23 per cent of all science students and 25 per cent of all students. This is likely driven by relatively higher numbers of postgraduate students on quantum courses than undergraduate students.
- Quantum students were predominantly male. Over 2019/20 to 2021/22, 76 per cent of quantum course entrants were male; this compares to 45 per cent of all science students and 42 per cent of all students.
- The proportion of quantum students who were UK-domiciled was substantially lower than across related disciplines. Over 2019/20 to 2021/22, 51 per cent of quantum course entrants were UK-domiciled students; this compares to 76 per cent of science students and 72 per cent of all students.
- The ethnicity distribution across quantum students at all levels was not markedly different from other similar cohorts. Over 2019/20 to 2021/22, 74 per cent of new entrants onto quantum courses identified as White; this compares to 71 per cent of science students and 72 per cent of all students.

## Methodology

This annex details analysis of HESA data using keywords to identify students studying courses that specialise in quantum technologies. While HESA publish data on related disciplines, to date there have not been any published data of students studying these courses. Therefore, we have developed this methodology in collaboration with industry experts and UKRI, HESA and other DSIT analysts to better understand the profile of students in this emerging field. This analysis also aims to contextualise the Taskforce's recommendations on training pathways, and diversity and inclusion.

Students on quantum specific courses captured in this analysis may not represent the full talent pipeline into quantum companies and research institutions. Only students studying courses with the keyword "quantum" appearing in the course title are captured, not those studying broader courses (e.g. Physical Sciences) which have quantum modules[footnote 77]. Categories of demographic information included are: sex, age, domicile, and ethnicity. The profile of quantum students is compared to cohorts in related disciplines (Physical Sciences, Mathematical Sciences, Engineering and Technology, Computing)[footnote 78], all science students and the entire student cohort.

All data aggregations are based on a sum of full-person equivalent (FPE) [footnote 79] instead of the count of instances. This ensures that students are not over or underrepresented based on the number of subjects their course covers. This is because a course can cover several subject classifications, creating duplications of student instances. FPE apportions the instances to indicate the proportion of a course that relates to each subject. Therefore, this analysis should not be directly compared to estimates produced using headcount data.

For the demographic breakdowns, we have used a 3-year average based on new entrant enrolments in each year. Using the stock of students to produce year-by-year breakdowns may bias the data by including students on multi-year courses in multiple years of data, while students on one-year courses will only appear in one year of data. Using new entrants ensures that the demographic breakdowns more accurately reflect the characteristics of individual students in the sector. This method is used by HESA in their published data[footnote 80]. Further information on the definitions used within HESA data is available online[footnote 81]. We have used a 3-year average across the 345 new entrant enrolments observed over the period 2019/20 to 2021/22[footnote 82] to ensure that we have a large enough sample of students to produce broadly representative estimates, given that student cohorts are relatively small year-to-year.

## Quantum student numbers

A simple count was undertaken of the number of students (i.e. the 'stock') studying a course with the word "quantum" in its title, by level of study and over the past 3 years for which data was available[footnote 83] (2019/20, 2020/21 and 2021/22). In 2021/22, there were 105 postgraduate taught students, 75 postgraduate research students and 15 undergraduate students. The data shows a steady increase in the number of postgraduate taught students, a slower growth in the number of postgraduate research students and a broadly flat profile for undergraduates[footnote 84].

Data on new entrants onto quantum courses (i.e. the 'flow') tells a broadly similar story. In 2021/22, there were 100 postgraduate taught entrants, 25 postgraduate research entrants and 5 undergraduate entrants. The data shows new entrants onto postgraduate taught programmes increased steadily year-on-year, while the profile remains broadly flat for undergraduate and postgraduate research programmes.

**Figure 1:** Quantum course total student count (FPE) by academic year and study level, UK, 2019/20 – 2021/22

Note: Estimates rounded to the nearest 5

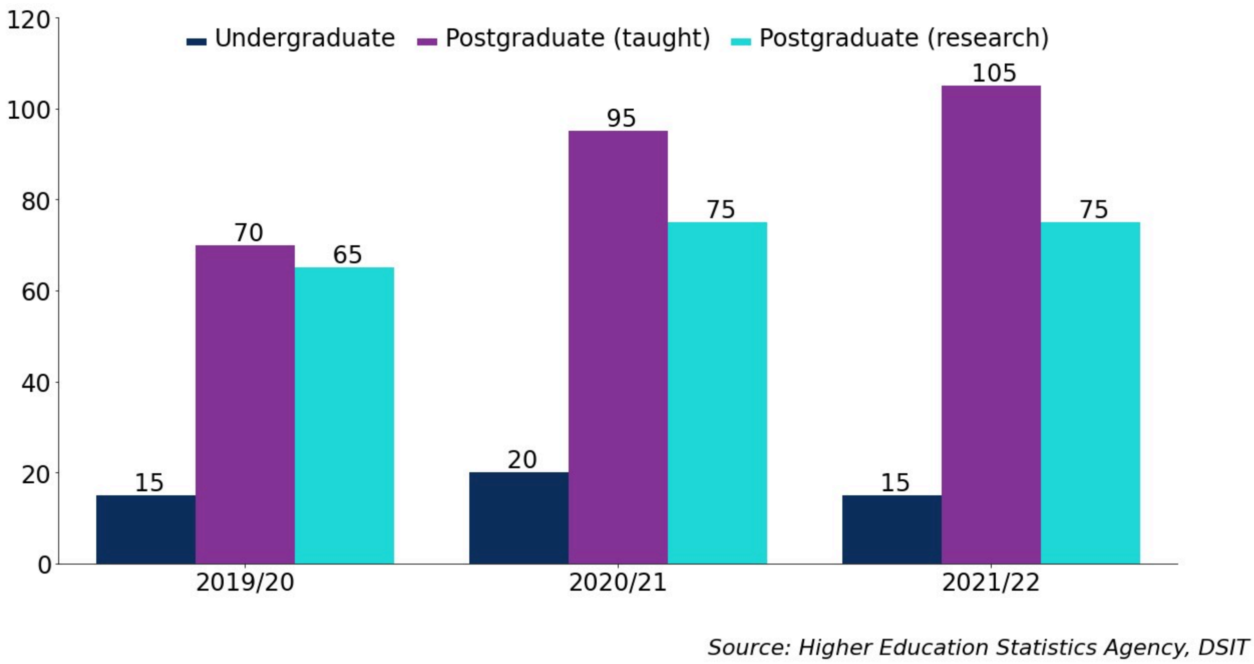
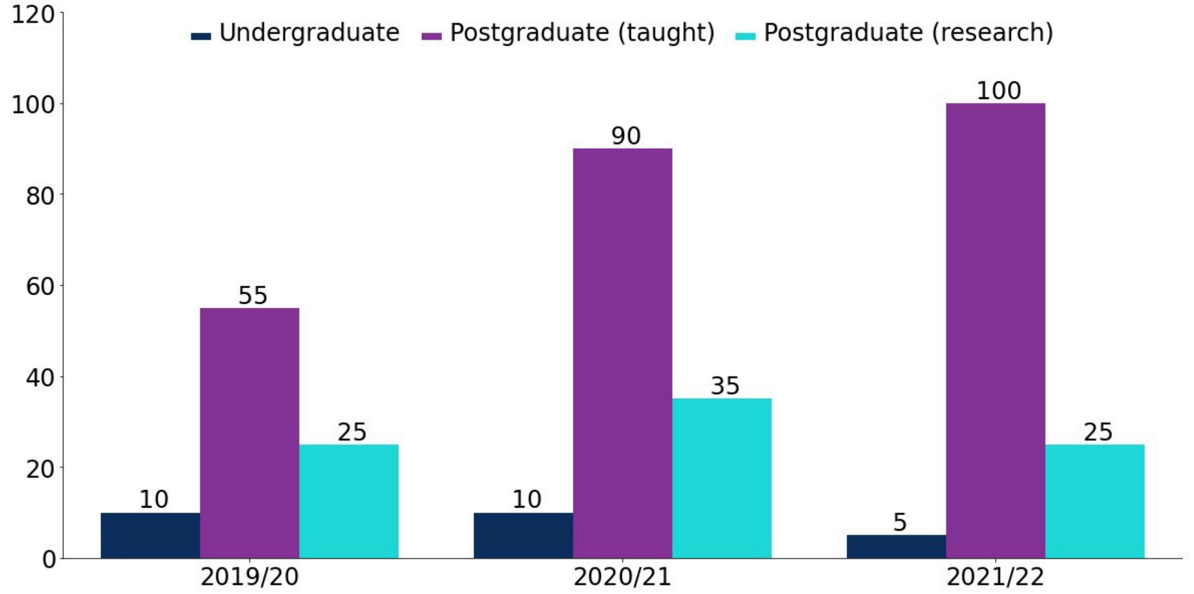



**Figure 2: Quantum course new entrants (FPE) by academic year and study level, UK, 2019/20 – 2021/22**




*Source: Higher Education Statistics Agency, DSIT*

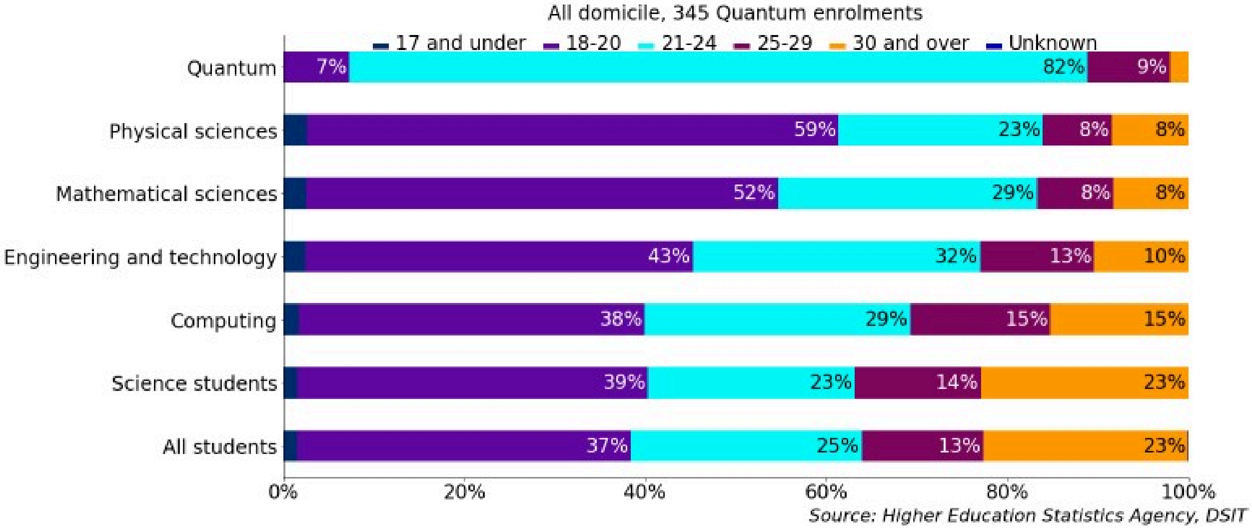
Note: Estimates rounded to the nearest 5

## New entrants by age

Between 2019/20 and 2021/22 inclusive, the age profile for quantum course entrants was markedly different from the profiles of wider cohorts. This is likely to be driven by the higher numbers of postgraduate students choosing to specialise in quantum relative to the numbers of undergraduates. By far the most prevalent age group across quantum student entrants was 21-24, at 82 per cent of the entrants captured in the data. This compares to 23 per cent of all science students and 25 per cent of all students. It should also be noted that the proportion of quantum students aged 30 and over is much lower than in wider cohorts, particularly when compared with the cohort of all science students and students across all disciplines.

**Figure 3:** All quantum student entrants (based on FPE) by age, UK, 2019/20 to 2021/22 average

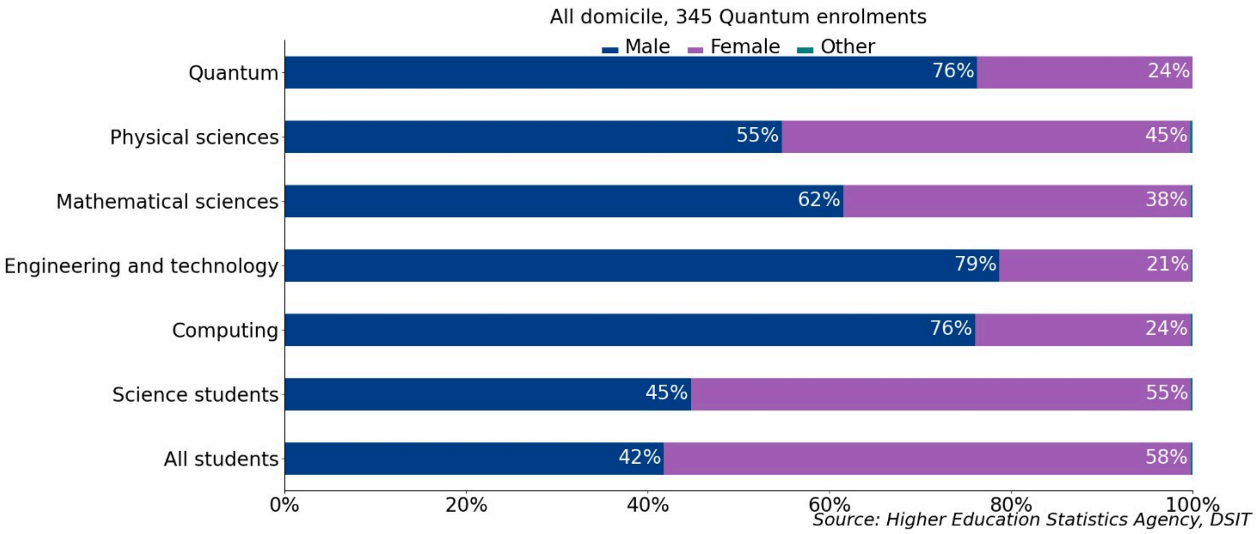
### Figure 3: All quantum student entrants (based on FPE) by age, UK, 2019/20 to 2021/22 average




## New entrants by sex

Between 2019/20 and 2021/22 inclusive, a significant majority (76 per cent) of new entrants onto quantum courses were male. This is broadly comparable to the Computing and Engineering and Technology profiles, but there was a notably higher proportion of male students than both Physical Sciences (55 per cent male) and Mathematical Sciences (62 per cent male). The degree of male dominance among quantum course entrants becomes yet more apparent when compared to the wider cohorts of science students (45 per cent male) and all students (42 per cent male).

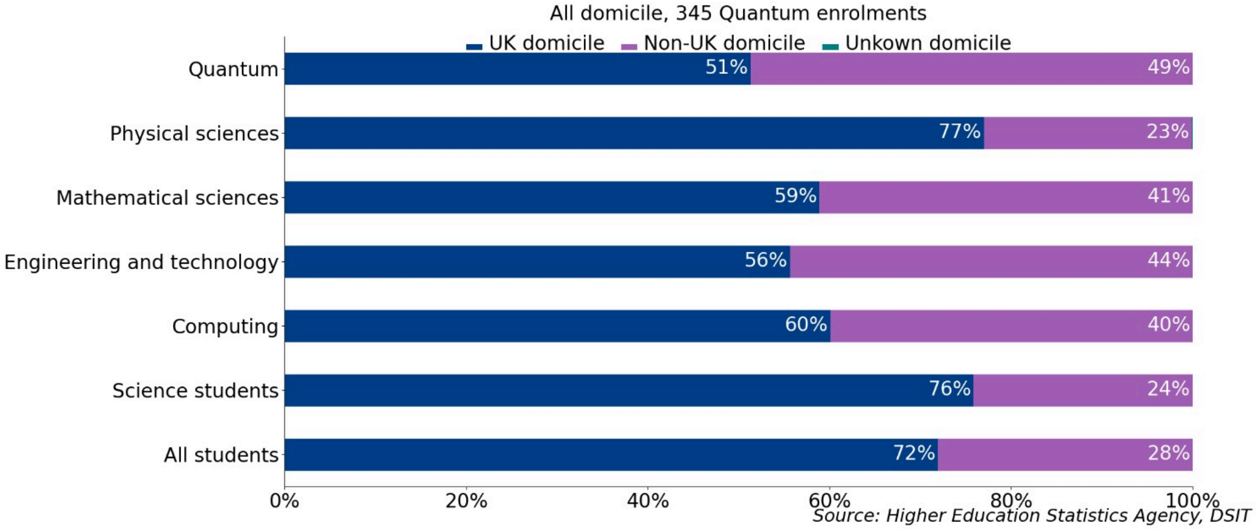
### Figure 4: All quantum student entrants (based on FPE) by sex, UK, 2019/20 to 2021/22 average




## New entrants by domicile status

Between 2019/20 and 2021/22 inclusive, the proportion of quantum course entrants who were UK-domiciled students was lower than across the 4 related disciplines, though to varying degrees. Physical Sciences had the highest proportion of UK-domiciled entrants across these disciplines at 77 per cent, followed by Computing at 60 per cent, Mathematical Sciences at 59 per cent and Engineering and Technology at 56 per cent. In comparison, 51 per cent of entrants onto quantum courses were UK-domiciled students. More broadly, 76 per cent of science students and 72 per cent of all students were UK-domiciled. This suggests that the UK is an appealing destination for overseas-domiciled students interested in quantum courses, relative to the related disciplines.

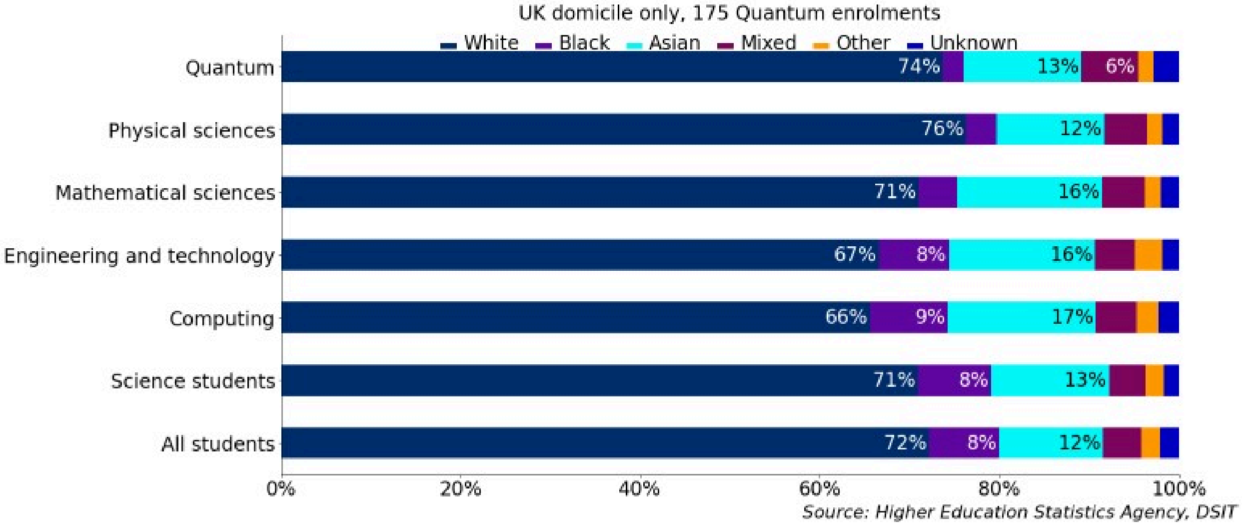
**Figure 5: All quantum student entrants (based on FPE) by domicile status, UK, 2019/20 to 2021/22 average**




## New entrants by ethnicity

Between 2019/20 and 2021/22 inclusive, the ethnicity distribution across quantum students at all levels was not markedly different from other similar cohorts, including all students and the cohort of all science students. Notably, the disciplines of Engineering and Technology and Computing had slightly more diverse profiles than quantum, but the Physical Sciences student profile was slightly less diverse than for quantum student entrants. It should be noted that ethnicity information is only available for UK-domiciled students; the chart below reflects this.

**Figure 6: UK-domiciled quantum student entrants (based on FPE) by ethnicity, UK, 2019/20-2021/22 average**




## Appendix A: Detailed breakdown of student counts and new entrants, by academic year, study level and domicile status

**Table 1:** Quantum student counts (based on FPE) by study level and domicile, UK, 2019/20 – 2021/22

| Study level | Domicile | 2019/20 | 2020/21 | 2021/22 | Total |
|---|---|---|---|---|---|
| Total | Total | 145 | 190 | 195 | 525 |
| Total | Non-UK-domicile | 50 | 90 | 90 | 225 |
| Total | UK-domicile | 100 | 100 | 110 | 305 |
| Postgraduate (research) | Total | 65 | 75 | 75 | 215 |
| Postgraduate (research) | Non-UK-domicile | 20 | 25 | 25 | 65 |
| Postgraduate (research) | UK-domicile | 50 | 55 | 55 | 155 |
| Postgraduate (taught) | Total | 70 | 95 | 105 | 265 |
| Postgraduate (taught) | Non-UK-domicile | 30 | 60 | 60 | 150 |
| Postgraduate (taught) | UK-domicile | 40 | 35 | 45 | 120 |
| Undergraduate | Total | 15 | 20 | 15 | 45 |

| | | | | | |
|---|---|---|---|---|---|
| Undergraduate | Non-UK-domicile | 0 | 5 | 5 | 15 |
| Undergraduate | UK-domicile | 15 | 15 | 15 | 35 |

Source: Higher Education Statistics Agency, DSIT

Note: Estimates rounded to the nearest 5

**Table 2:** Quantum student entrants (based on FPE) by study level and domicile, UK, 2019/20 – 2021/22

| Study level | Domicile | 2019/20 | 2020/21 | 2021/22 | Total |
|---|---|---|---|---|---|
| Total | Total | 90 | 135 | 125 | 345 |
| Total | Non-UK-domicile | 35 | 75 | 65 | 170 |
| Total | UK domicile | 55 | 60 | 60 | 175 |
| Postgraduate (research) | Total | 25 | 35 | 25 | 85 |
| Postgraduate (research) | Non-UK-domicile | 5 | 15 | 5 | 20 |
| Postgraduate (research) | UK-domicile | 25 | 25 | 20 | 65 |
| Postgraduate (taught) | Total | 55 | 90 | 100 | 245 |
| Postgraduate (taught) | Non-UK-domicile | 30 | 60 | 60 | 145 |
| Postgraduate (taught) | UK-domicile | 30 | 35 | 40 | 100 |
| Undergraduate | Total | 10 | 10 | 5 | 20 |
| Undergraduate | Non-UK-domicile | 0 | 5 | 0 | 5 |
| Undergraduate | UK-domicile | 5 | 5 | 5 | 15 |

Source: Higher Education Statistics Agency, DSIT

Note: Estimates rounded to the nearest 5

## Appendix B: Detailed methodology notes

This analysis was produced using Higher Education Statistics Agency (HESA) student data. HESA student data is a rich and comprehensive dataset that includes detailed records of students enrolled in higher education institutions in the UK. The record collects a wide range of information, including data about students' personal characteristics, courses and modules of study, and qualifications achieved. Each student record is anonymised to protect individual identities, and the data used spans the academic years 2019/20 to 2021/22.

The data provided by HESA are legacy data (data collection 051) so comparator subject demographic metrics may not exactly match open HESA data due to differing data versions. The analysis follows the HESA suppression and rounding requirements (https://www.hesa.ac.uk/about/regulation/data-protection/rounding-and-suppression-anonymise-statistics).

Quantum courses are identified on the keyword "quantum" appearing in the course title. Students' data are aggregated based on their Full Person Equivalent (FPE). This ensures that students aren't over or underrepresented based on the number of subjects their course covers. This is because a course can cover several subject classifications, creating duplications of student instances. FPE apportions the instances to indicate the proportion of a course that relates to each subject.

Demographic comparisons are based on student enrolments across the period 2019/20 to 2021/22. Ethnicity analysis (https://www.hesa.ac.uk/collection/c21051/a/ETHNIC) is only for UK-domiciled students. For further information on the Ethnicity or Sex variables please see the HESA collection metadata (https://www.hesa.ac.uk/collection/c21051/). Ethnicity groupings mirror those found here: HESA table 45 - HE student enrolments with a permanent address in the UK by subject of study and ethnicity 2014/15 to 2022/23 (https://www.hesa.ac.uk/data-and-analysis/students/table-45).

Comparative subject groupings use the Common Aggregation Hierarchy (CAH) which provides a standardised hierarchical aggregation (grouping) of HECoS (Higher Education Classification of Subjects) codes (https://www.hesa.ac.uk/collection/coding-manual-tools/hecoscahdata/hecos) and terms. The science grouping is an aggregation of CAH level 1 codes CAH01 through to CAH13 and CAH26 except for CAH26-01-03 (Human geography). CAH26 (Geographical and environmental studies) has been disaggregated so that CAH26-01-03 (Human geography) is presented in the non-science grouping labelled as ‘Geographical and environmental studies (social sciences)’. All other CAH level 3 codes within CAH26 are presented in the science grouping labelled as ‘Geographical and environmental studies (natural sciences)’. This grouping of science subjects has been created by HESA.

# Taskforce Additional Evidence Annex

This annex sets out further detail on evidence underpinning statements made in the Quantum Skills Taskforce report, summarised in the below table. It contains information on methodologies, variable definitions and limitations.

| Statement | Evidence |
|---|---|
| ‘Based on 2022-23 data from HMRC, the UK quantum sector employs around 1,700 people, with an average salary of approximately £60,000.’ | HMRC analysis |
| ‘As quantum technologies have advanced, the demand for suitably qualified candidates has increased dramatically’ | Lightcast vacancy data analysis |
| ‘Quantum computing has also been the main contributor of increases to the number of job vacancies in the quantum sector.’ | Lightcast vacancy data analysis |

## HMRC analysis

The Taskforce report states ‘Based on 2022-23 data from HMRC, the UK quantum sector currently employs around 1,700 people, with an average salary of approximately £60,000.’ This statement is based on analysis of HMRC data, further detail on which is set out below.

**Data matching:** To investigate the economic performance of the quantum sector, DSIT provided HMRC with a list of company registration numbers (CRNs). These CRNs were identified through the development of a Real Time Industry Classification (RTIC) for the quantum technology sector, in conjunction with The Data City and sector experts in Spring 2024[footnote 85].

There is a 100% match rate between the list of CRNs provided for the quantum sector and HMRC's dataset.

**Subsidiaries:** The identified companies include subsidiaries, so the company count is therefore likely to be an overestimate of the total number of companies in the sector. There was no clear methodology for assessing which subsidiaries should be excluded, therefore this approach was taken so that we do not miss any data relevant to a company and the sum of key metrics for the sector is accurate[footnote 86].

**Data coverage:** Despite the 100% match rate, data coverage for specific variables is not complete, and is summarised in the table below. For instance, for the year 2018-19, 75 per cent of companies in the matched dataset of quantum companies reported an annual turnover figure.

**Table 1:** Variable Coverage Rates

| Year | Annual Turnover[footnote 87] | GVA[footnote 88] | Partially Gross Trading Profit | Employee Variables[footnote 89] |
|---|---|---|---|---|
| 2018-19 | 75.0% | 68.3% | 80.0% | 70.0% |
| 2019-20 | 76.8% | 73.9% | 84.1% | 76.8% |
| 2020-21 | 80.0% | 73.3% | 88.0% | 73.3% |
| 2021-22 | 79.5% | 76.9% | 88.5% | 80.8% |
| 2022-23 | 74.7% | 73.3% | 88.4% | 74.4% |

**Dedicated vs diversified companies:** The companies from the RTIC included in this analysis were those that sit completely within the sector (dedicated companies) and not large companies that happen to have a strand of business in the sector (diversified companies). This was to avoid, as far as possible, the inclusion of economic activity of large, diversified companies with only a small level of activity in the quantum field, as this would lead to significant overestimations. With this is in mind, for most of the analysis, HMRC and DSIT jointly chose to remove the large, diversified companies from the dataset by categorising them based on 3 variables. A company was classified as large and diversified if any of the following were true in the first year that variable was reported:

- Employee number > 250
- Turnover > £36 million
- Tangible assets > £18 million

By requiring only one of these statements to be true, this approach is more likely to classify a company as large and diversified than the Companies Act would, increasing the likelihood that the diversified companies have been removed. Notably, this also mitigates issues surrounding missing data, allowing every company to be classified regardless of the number of variables missing or available for that company.

**Summary of outputs:** HMRC then summarised each of the variables of interest and the number of dedicated quantum companies reporting that variable of interest, over 5 years from 2018-19 to 2022-23. Specifically, they calculated the following variables for the companies in the group of interest and report these as the total, or average, in the sector:

- Total Annual Turnover: The trading turnover earned in the financial year annualised according to that company's accounting period for the given year.
- Employee Count: Calculated using the number of active National Insurance Numbers that were paid in the financial year. We include the total employee count and the median[footnote 90] employee count in the sector.
- Total Wages: Calculated as total employee pay, plus pension contributions, plus other staff costs for all companies in the dataset[footnote 91].
- Average Employee Pay: Calculated as total employee pay divided by total employee count, to give mean employee pay across all companies in the dataset, per year[footnote 92].
- Total Partially Gross Trading Profit (PGTP): Defined as net trading profit, plus capital allowances (CAs), less CA balancing charges[footnote 93].
- Total Gross Value Added (GVA): Calculated as Partially Gross Trading Profit plus Wages, as defined above.

The outputs for the above variables, covering dedicated companies only for the year 2022-23, are set out in the table below.

**Table 2:** Summary of Outputs, Dedicated Companies only, 2022-23

| Variable | Value | No. of companies reporting |
|---|---|---|

| | | |
|---|---|---|
| Total Annual Turnover | £216,300,000 | 54 |
| Total Employee Count | 1,680 | 54 |
| Median Employee Count | 13 | 54 |
| Total Wages | £102,100,000 | 54 |
| Average Employee Pay | £60,000 | 54 |
| Total PGTP | -£90,900,000 | 67 |
| Total GVA | £11,700,000 | 54 |

## Lightcast vacancy data analysis

The Taskforce report states: ‘as quantum technologies have advanced, the demand for suitably qualified candidates has increased dramatically’; similarly, the report states ‘[Quantum computing] has also been the main contributor of increases to the number of job vacancies in the quantum sector.’ These statements are based on experimental analysis carried out by DSIT, using data on job vacancies obtained from Lightcast, a commercial provider[footnote 94]. Further information, including limitations, on this analysis is set out below.

**Analysis of online job advertisements:** To better understand the UK quantum technology workforce and recruitment landscape, DSIT have carried out exploratory analysis of online job vacancy data in the sector from Lightcast. Lightcast data contains details on millions of online job advertisements posted in the UK from 2014 to the present day. As the data is obtained via web scraping, the advertisements will be biased towards job roles that are more likely to be advertised online, such as managerial and professional jobs. Additionally, the web scraping process cannot guarantee to cover all job sites and portals.

**Time period and keyword search:** This analysis considers online jobs posted between 1 Jan 2014 and 31 Jan 2025. Job vacancies in the Quantum Technology sector were identified by searching for keywords in the text of the job vacancy. The keyword search was insensitive to case and some punctuation, e.g. a search for ‘Machine Learning’ would also match ‘machine-learning’. The list of keywords was developed in conjunction with the Government Office for Science.

**Headline findings:** As of 31 January 2025, the number of job vacancies for the Quantum Technology sector reached a 3-month rolling average[footnote 95] of 114, or 0.02% as a share of all job vacancies in the dataset. This is a very significant increase on the equivalent estimate from ten years prior: in January 2015, the 3-month rolling average of the number of job vacancies in the Quantum Technology sector was 15, or 0.004% as a share of all job vacancies in the dataset. Since January 2021, the key word 'Quantum Computing' has accounted for the highest 3-month rolling average share of vacancies in the dataset, indicating that it has been a significant driver of the growing number of vacancies in the sector.

**Limitations:** The data represents job adverts being posted online - it is not a measure of active online vacancies at a certain point in time. The data only shows that the vacancy was advertised. It does not show whether the vacancy is still active. While filtering by keywords is a useful method to identify relevant jobs, not all jobs captured will pertain to the sector. Similarly, the choice of keywords means that some relevant jobs may not be identified. As the overall job counts for the Quantum Technology sector are low, additional caution should be taken when interpreting outputs as patterns may be due to the volatility associated with low numbers rather than a true reflection of the underlying job trends. Although the data supplier seeks to remove duplicate job advertisements, this process is not guaranteed to be fully effective, thus there is a risk that the data contains some duplicated jobs.

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82. Most recent data available at the time of writing.
83. Analysis based on student legacy data, further information available here (https://www.hesa.ac.uk/collection/c21051/)
84. It should be noted that the undergraduate student total is markedly lower than the postgraduate totals. This is likely due to the fact that most undergraduates of school-leaving age tend to enrol onto broader degree programmes (e.g. Physics or Mathematics) and are less likely to identify a specialism such as quantum at this stage in their careers.
85. Data City Quantum RTIC (https://thedatacity.com/rtics/quantum-technology-rtic0087/)
86. Despite the inclusion of subsidiaries, double counting is not an issue as there is no duplication of reporting of economic activity to HMRC across company subsidiaries.
87. Turnover is not a mandatory field on the CT600 return, so coverage is likely to be lower than mandatory fields such as profit.
88. Gross Value Added (GVA) is calculated from a combination of other variables, therefore coverage is lower.

89. Employee variables are only available where a company is PAYE registered and where it has been possible to match a CRN to a payroll scheme. As the company lists include subsidiaries, we would not expect each CRN to have a payroll scheme, which impacts coverage rates.
90. Per business, per year.
91. Employee pay is a company's total expenditure on staff wages and salaries. Pension contributions are employee pension contributions. Other staff costs includes examples such as statutory sick or maternity pay, ordinary or additional paternity pay, and adoption pay. We do not have an employer pension contribution variable in the dataset.
92. Total employee pay is the sum of all companies' expenditure on employee pay in the sector. Total employee count is the sum of all companies' employee counts in the sector.
93. CAs are a form of tax relief on capital expenditure with the purpose of incentivising investment. They are a positive indicator of the health and growth of investment-based companies like those covered by this analysis.
94. Lightcast (https://lightcast.io/uk)
95. Covering November 2024, December 2024 and January 2025.

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