Research Consulting

Demand for cohort-based doctoral training in metamaterials in the UK

Industry and research user skills needs and perspectives

A report for The UK Metamaterials Network

February 2023

Demand for cohort-based doctoral training in metamaterials in the UK

Report commissioned by:

The UK Metamaterials Network, via The University of Exeter.

www.metamaterials.network

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Executive Summary

The UK Metamaterials Network (the UKMMN) brings together experts from academia, industry, and government agencies to resolve interdisciplinary challenges for this exciting field of emerging materials from theory, fabrication, experiment, to large-scale manufacturing and field testing. In September 2022, the UKMMN commissioned Research Consulting (RC) to support the design, analysis and reporting of a survey focused on industry and research user perspectives of doctoral skills and training in metamaterials. The survey explored employer perceptions of the skills needs and available in doctoral graduates, the impacts this has on industry, and how any skills gaps can be addressed. The primary purpose of the report is to inform the development of future programmes for doctoral training, including the forthcoming call for EPSRC Centres for Doctoral Training.

This report summarises the results and recommendations from the work. The survey captured quantitative and qualitative information from individuals within selected industry and R&D organisations. Responses were received from 23 individuals representing insights from organisations in different sectors, of different sizes, who are involved in the UKMMN or the existing Centre for Doctoral Training (CDT) in this area. Responding organisations are active collaborators with universities and significant employers of doctoral graduates. The report covers six areas linked to doctoral training and employer requirements in terms of skills, industrial R&D and the longer-term uptake of metamaterials:

- Working with universities
- Doctoral training and recruitment of skills
- Opportunities and challenges
- Training and Development
- Future needs
- UK competitiveness

Responses identify metamaterials as an area of emerging opportunity for the UK, with acknowledged strengths in the underpinning science and need to see this successfully translated into a range of commercial applications. Doctoral training will play an important part in this, but wider support from the UK's research and innovation funders is needed to support specific projects and (importantly) networking across R&D and supply chain organisations.

Physics, engineering and materials science disciplines are most commonly sought when employing doctoral-level graduates. There is a strongly perceived challenge in recruiting individuals with the right technical and soft skills. Demand for doctoral skills is expected to increase over the next 5 years. When seeking to employ doctoral students the importance of strong technical skills in terms of the subject area and discipline are sought, but what emerges strongly is the importance of a wider set of knowledge, competencies and behaviours critical to successful progression into industrial R&D employment.

The added value of CDT-based doctoral training is recognised by these employers and is identified as (i) enhanced skills and experience of individual students, and (ii) in terms of the CDT providing industry partners with access to a wider range of research, relevant networks (academic and industry) and a pool of students (for potential recruitment).

The report makes a number of recommendations for the development and design of a future centre for doctoral training in this area. These include:

- Build on the perceived industry benefits from participation in centre-based doctoral study, identifying ways to enhance and expand the benefits to industry and supply chain partners.
- Working with industry partners to develop and enhance the training programme, supporting wider skills in doctoral students, including industry partners to augment the awareness and appreciation of commercial and research exploitation issues.
- Expanding the range of organisations willing and able to host doctoral students on short placements relevant to the wider application and commercial landscape for metamaterials
- Actively develop and incorporate measures to address diversity and underrepresentation in the recruitment of students to post-graduate research study in this area.

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1. Introduction and background

1.1 Purpose of this report

A survey of industry perceptions and needs relating to metamaterials R&D and related doctoral skills training and talent.

In September 2022, The UK Metamaterials Network (the UKMMN), via The University of Exeter, commissioned Research Consulting (RC) to support the design, analysis and reporting of a survey focused on industry and research user perspectives of doctoral skills and training in metamaterials. The survey explored employer perceptions of the skills needs and available in doctoral graduates, the impacts this has on industry, and how any skills gaps can be addressed.

The current report aims to provide an overview of the project and results, and is split into three main sections:

- Introduction and background (Section 1)
- Findings from the survey (Section 2)
- Conclusions and recommendations (Section 3)

1.2 Overview and context

The UK Metamaterials Network aims to build a community to accelerate innovative metamaterial research

The UK Metamaterials Network brings together experts from academia, industry, and governmental agencies to resolve interdisciplinary challenges for this exciting field of emerging materials from theory, fabrication, experiment, to large-scale manufacturing and field testing. The key aim is to build a vibrant and creative, multidisciplinary community to accelerate novel and innovative metamaterials research and exploitation pathways, while securing and building the UK's sovereign capability and prosperity in this crucial scientific area.

The aims of this research and survey

The aims of the conducted research were to enable an understanding of UK based industry, government agencies, and national labs, in terms of the metamaterials area and their perspective on the following issues:

- recruitment requirements for doctoral graduates, training and related skills;
- current employment landscape of doctorial training graduates (including the subject areas of graduates);
- relationships with, and perceptions of, universities and doctoral training centres;
- perceived skills gaps in employees with doctoral training and the perceived impact of this on the organisation/industry;
- perceived future needs of the organisation/industry and whether/how doctoral training and skills fit in to this; and
- challenges in recruiting postdoctoral graduates from a diverse range of social and economic backgrounds.

EPSRC Centres for Doctoral Training

The purpose of the information gathered from the survey is to inform the development of collaborative university-industry proposals to the forthcoming EPSRC Centres for

Doctoral Training. The aim of the Centres for Doctoral Training is to produce the next generation of internationally recognised doctoral researchers to address key interdisciplinary engineering and physical science needs, aligned to regional, national and global priorities across academia, industry, and other sectors.

1.3 Methodology and approach

The survey was co-created by Research Consulting and the UK Metamaterials Network Team

The survey was co-created though an iterative process, which included a pilot stage that tested the survey with a small number of stakeholders and was informed by a previous survey. A link to access this survey was produced by the Research Consulting team and provided to The UK Metamaterials Network team for distribution to organisations.

The survey was disseminated by The UK Metamaterials Network team directly to 32 organisations.

The survey explored 6 key areas

In overview, the survey explored the following areas:

- Working with universities
- Doctoral training and recruitment of skills
- Opportunities and challenges
- Training and Development
- Future needs
- UK competitiveness

The survey generated 23 responses, primarily from individuals in private industry.

There was a total of 23 responses from 21 organisations. See Appendix B for more information on the participating organisations.

Respondents hold senior roles within their organisations, from organisation level leadership such as CEO or CTO, to R&D leadership or senior management, project management, product development scientists, research scientists, and the head of specific technical organisational functions. They are therefore well placed to address the survey questions from strategic, operational, and future needs perspectives.

Data analysis

A mix of both qualitative and quantitative data analysis techniques were used to analyse the survey results and generate the insights shared in the report. Where free-text comments were reported, these were assessed to identify key themes and grouped issues.

Limitations of the study include a small sample size of known contacts

The survey was designed to be completed by representatives of the organisations already engaged in metamaterials work and research collaboration with universities involved in the UK Metamaterials Network and current centre for doctoral training. The work is subject to several limitations, including:

- The work was completed from September 2022 to January 2023, while the survey ran from December 2022 to January 2023, to ensure it met the required timescales set by the University and The UK Metamaterials Network. The findings therefore represent a snapshot of the challenges and needs at this time.

- A relatively small sample size was gathered, of known contacts, therefore, while the findings may be representative of organisations in contact with The UK Metamaterials Network, they may not be representative of the wider UK landscape.

Data protection and confidentiality

For the purposes of public dissemination, this report does not identify which data is associated with specific organisations. All survey responses and quotes have been anonymised. Organisations full survey responses are considered confidential and were only accessible to the project team.

All data collected through the survey and held by Research Consulting is stored in cloud servers based in the territory of the European Union, in compliance with relevant privacy regulations and with Research Consulting's Data protection and privacy policy.

Acknowledgements

The project team at Research Consulting gratefully acknowledge the support of the University of Exeter and The UK Metamaterials Network team in the delivery of this project.

In particular, we appreciate the useful support and guidance from Dr Anja Roeding (Co-Founder and Operations & Relations Lead of the EPSRC UK Metamaterials Network) and Professor Alastair Hibbins (joint lead of the EPSRC UK Metamaterials Network, Director of Exeter's Centre of Metamaterials Research and Innovation and the associated doctoral training centre for PhD students).

We would also like to thank the organisations who generously gave their time, provided feedback on the survey design, and through their participation which provided the evidence on which this report is based.

2. Findings from the survey

Overview of this section

This section details the survey findings. The findings are laid out in 6 sections, organised according to the themes of questions in the survey. These are as follows:

- Working with universities (section 2.1)
- Doctoral training and recruitment of skills (section 2.2)
- Opportunities and challenges (section 2.3)
- Training and Development (section 2.4)
- Future needs (section 2.5)
- UK competitiveness (section 2.6)

2.1 Working with universities

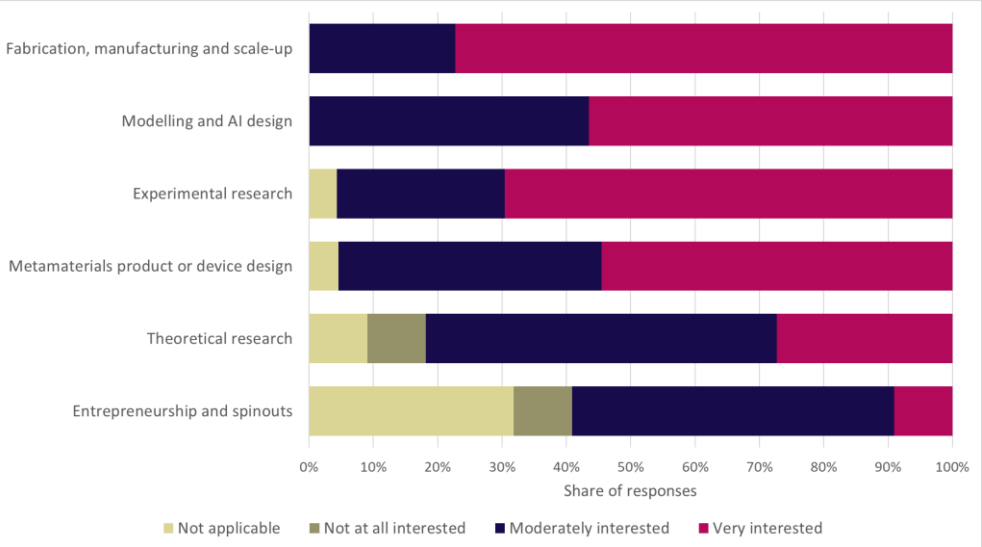
Organisations are interested in Fabrication, manufacturing and scale up.

Respondents reported high interest into recruiting into the areas of Fabrication, manufacturing and scale up, Modelling and AI design, and experimental research. See Figure 1.

Recruiting into Entrepreneurships and spinouts was not applicable for 32% of organisations who participated in this research. One organisation additionally recorded moderate interest in Technical Project Management.

Figure 1: Interest of organisations into different recruitment areas (n=23)

"What areas are you most interested in recruiting into?"



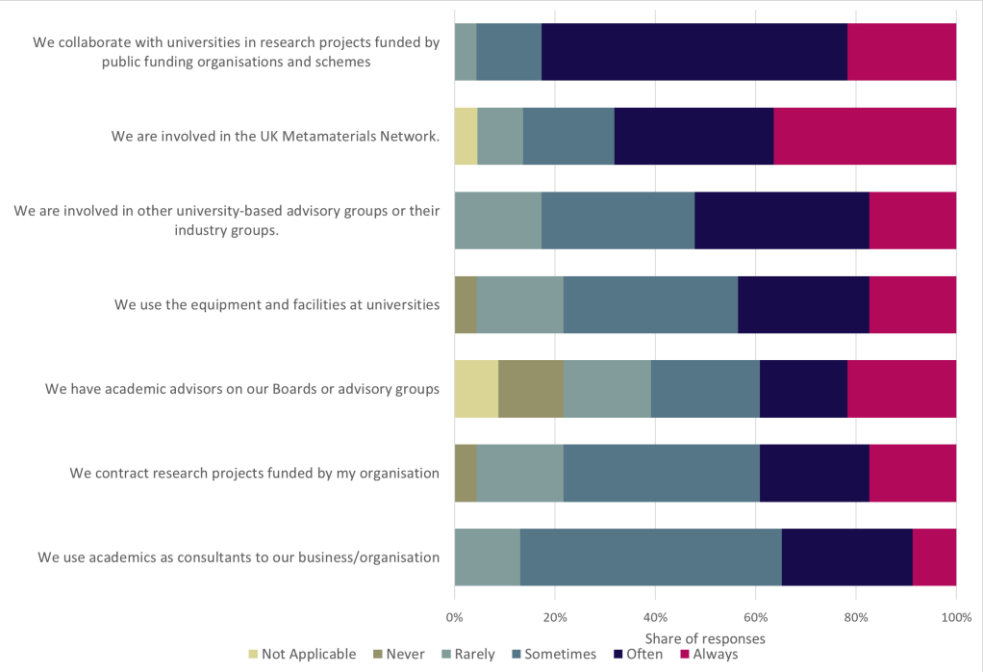
Collaborations with universities for research projects are frequently undertaken by organisations.

The organisations in this survey are active collaborators with universities. The majority of respondents indicate that they work with multiple pathways that support engagement (respondents reporting at least "sometimes", "often" or "always" to each form of collaboration. See Figure 2.

Collaboration on research projects funded by public organisation is the most intensively reported form of engagement: over 80% of respondents indicating often/always to this form of collaboration.

Figure 2: Interactions with Universities in wider forms of collaboration (n=23)

"How often do you work with universities and doctoral students in each of the following areas?"



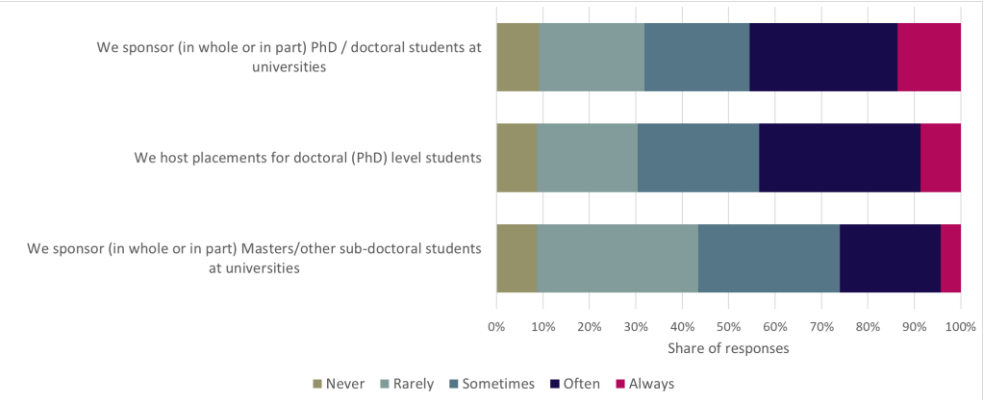
Scope to expand the range of organisations hosting doctoral placements

Around 45% of responses indicate that participants are sponsoring doctoral students or hosting placements for doctoral students on an often/always basis. See Figure 3.

It would be reasonable to anticipate that we may have observed more organisations *hosting* placements than *funding/co-funding* doctoral students. The similarity of the two responses suggests that there may be scope to expand the range of organisations hosting doctoral placements – a lower level of commitment - when funding for doctoral students might not be available to that organisation. Survey responses indicate that around a third of responding organisations rarely or never host doctoral placements. Only 45% report doing so on an often or always basis.

Figure 3: Interactions with doctoral students (n=23)

"How often do you work with universities and doctoral students in each of the following areas?"



96% of respondents hoped to pursue research that would otherwise be impossible by

When asked to identify the benefits that they hoped to gain as an organisation, from collaborating with universities through centres for doctoral training, 96% (22 of 23) of respondents indicated the opportunity to pursue research that they would otherwise be unable to pursue. (Figure 4). 87% also highlighted direct contact with students and academics as a desired benefit. When provided the opportunity to detail additional

collaborating with universities

benefits, topics such as recruitment, the sharing of equipment and expertise, and links to industrial R&D at higher levels of technological readiness were identified.

The benefits sought by industry partners in collaborations with CDTs: ability to pursue otherwise impossible research and direct engagement with students and academics.

"What specific benefits would you wish to secure as an organisation from collaborating with universities through centres for doctoral training?"

The survey asked respondents about the specific benefits they wish to secure as an organisation from collaborating with universities through centres for doctoral training. Figure 4 outlines responses relating to the specific benefits sought by industry partners in their collaborations with universities through centres for doctoral training. The opportunity to pursue research that would otherwise be impossible for the organisation and direct contact with students and academics were cited by almost all respondents.

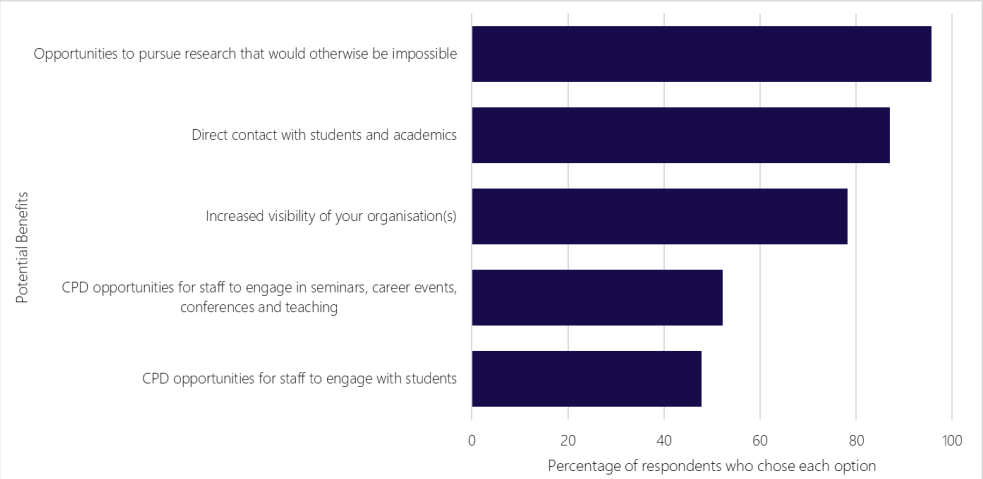
CPD opportunities for staff were perceived as benefit for about half of the responding organisations.

Additional comments indicated benefits in terms of recruitment (covered elsewhere in the survey), access to shared equipment and R&D expertise and links to industrial R&D at higher TRL levels.

"The ability to have a conversation with research staff and academics often provokes ideas and actions that would never happen in the daily noise of manufacturing. It is a vital resource to at least have a conversation so we can view and appreciate concepts and ideas in different contexts."

Figure 4: Benefits organisations wish to secure (n=23, multiple responses allowed)

"What specific benefits would you wish to secure as an organisation from collaborating with universities through centres for doctoral training?"



Exploring areas of potentially important R&D emerged as the most important reason for interest in doctoral training.

Please consider the potential reasons for involvement and interest in doctoral training. How important are these options to your organisation?

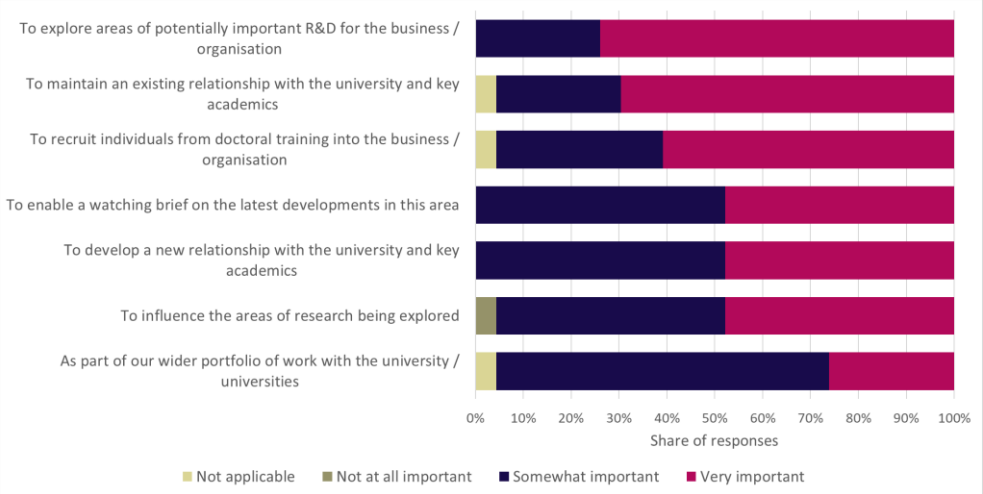
The survey explored the reasons participants engaged in doctoral training, ranking the importance of selected drivers for engagement. Across all of the options presented there was a high level of perceived importance, figure 5. Three options emerged as leading reasons, based on the proportion rating these as "very important":

- to explore areas of potentially important R&D for the business / organisation.
- to maintain an existing relationship with the university and key academics; and

- to recruit individuals from doctoral training into the business / organisation

Figure 5: The importance of drivers for engagement in doctoral training (n=23)

"Please consider the potential reasons for involvement and interest in doctoral training. How important are each of the below to your organisation?"



2.2 Doctoral training and recruitment of doctoral skills

Doctoral skills are commonly found in participants' organisations and functional areas.

How many of your current employees have a doctorate? Is this for your organisation as a whole, or for a specific area?

The survey respondents directly benefit from doctoral skills in their current employees. Respondents indicated that individuals with doctorates are commonly found in their current organisational and departmental employees. We do note however, that for most respondents this response necessitated a degree of estimation.

Between 10 and 20% of existing employees holding doctorates was commonly stated, and for around a third this exceeded 50%. This rose to 80-90% in a few cases where the responses considered specific R&D or technical functions.

74% of organisations reported seeking to employ individuals with a doctorate or doctorate research experience and skills as part of their wider experience.

To what extent do you explicitly recruit people with a doctorate degree?

The survey explored the extent to which participants *explicitly* recruit people with a doctoral qualification. For the majority of responses doctoral level skills are an important aspect in recruitment of employer skills:

- 61% of respondents 'frequently sought to employ individuals with doctoral research qualifications or experience'; and
- a further 13% sought individuals with a doctorate degree as part of the 'rounded experience and skills sought in individuals'.

Others indicated that they didn't seek doctoral level qualifications explicitly, but did employ individuals with doctoral-level qualifications.

(Due to our size) "the company is not ready to explicitly recruit at doctorate level, however we aim to in the future and will require individuals with a rounded skill set."

"We only hire PhD's with specific, relevant domain knowledge."

The added value of CDT-based doctoral training: broader skills and awareness; improved networks and access to a wider body of research

What added value do/would you gain from recruiting doctoral graduates out of a cohort-based CDT rather than from lone-scholar projects?

The survey sought to understand the added value that CDT-based doctoral training provides for industry partners. The (free-text) responses consistently point to three areas where respondents perceived benefits, and these align strongly to their stated requirements in future recruitment and skills needs:

- the development of broader skills and awareness of the wider field (industrial R&D contexts);
- improved connectivity – at company and individual (student) levels; and
- access to a wider body of research.

"A warranty that students have received the required base training in metamaterials, nano photonics, and, hopefully, standards of project practices."

...the development of broader skills.

The development of broader skills emerges strongly as a perceived benefit of CDT-based doctoral training (compared to individual PhD projects) This includes awareness of the wider field and progression from research into development / industrial R&D contexts.

"I believe that graduates that have been part of the CDT will be more rounded in their skill sets both, technically and personally....they are encouraged to collaborate and to invest time in other peoples' work and ideas."

"Cohort based candidates often display wider understanding and a more holistic view of the entire field and associated challenges."

"Scientists who can independently work out a path towards achieving a technical task and deliver quality results quickly."

...improved **connectivity** and networks.

Improved connectivity and networks – at company and individual levels. For the company this relates to the CDT providing collaborating partners with access and connectivity to a wider range of possible recruits. One respondent also noted that the CDT context better enabled a closer alignment to their company strategy and ethos.

At an individual level the doctoral students are perceived to gain an enhanced personal network, viewed as a valuable asset to these potential future employers. Academic and industry networks are both important in this aspect.

"(They) have greater experience of working in a team-based research culture and likely come with a wider and stronger knowledge base and network."

"Links with the cohort - some of whom will be employed by companies in the same / similar field."

… access to a wider body of research

Access to a wider body of research- which strongly aligns to the leading driver for engagement in figure 5. Responses to other parts of the survey indicate industry perceived needs around improving business-to-business networking - for start-ups and across supply chains / sectors – these are areas where the CDT provides additional supporting infrastructure.

"We look to recruit from centres of excellence on key topics that will drive technology development. When we do this we look for broad subject matter expertise and a very strong network. CDTs provide a perfect platform to enable these characteristics in the next generation of scientists and technologists."

"(They) influence company attitudes towards key areas of development."

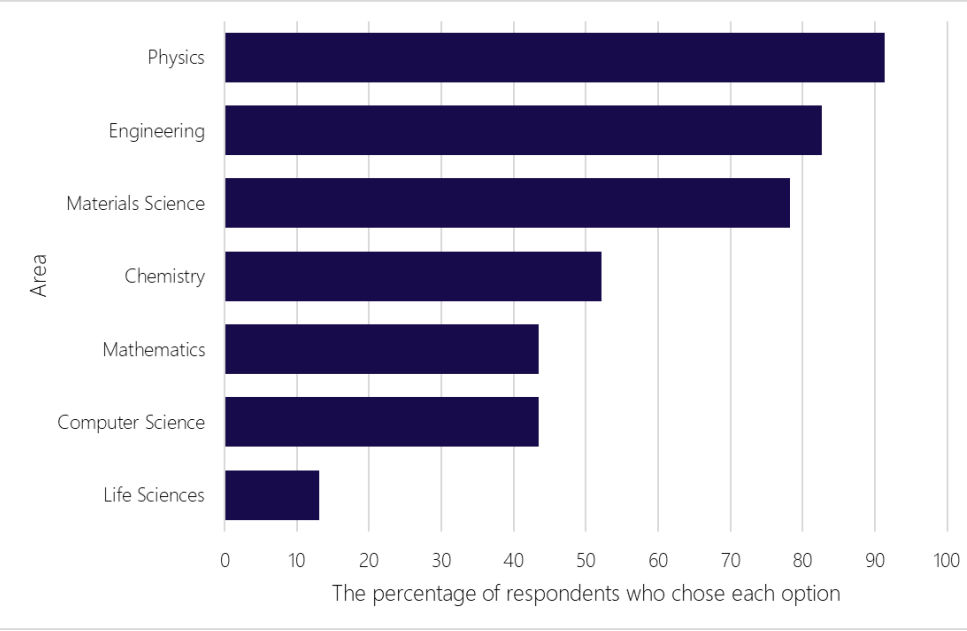
Strong demand for physics, engineering, and materials science doctoral graduates

Physics, engineering, and materials science emerged as the most frequently sought disciplinary background for employment of doctoral graduates (figure 6).

Free text responses indicated needs in areas of metamaterials development aligned to manufacturing and for specialist sectors, including biotech, food and nutritional science and environmental sciences.

Figure 6: Scientific backgrounds typically sought after when employing doctorate level graduates (n=23)

"If you are employing doctoral level graduates, which scientific backgrounds are typically sought?"



An individual's ability to communicate, collaborate, be flexible and adaptable and pick up new ideas / developments quickly are highly ranked by employers

The survey explored employer views on the skills or behaviours expected from doctoral graduates at the start of employment. Pre-defined options and additional free-text responses were captured.

The distribution of responses to the pre-defined options are shown in Figure 7. All respondents expect doctoral graduates to have the ability to pick up new ideas/developments quickly, alongside holding subject-specific knowledge and technical skills (ranked #2).

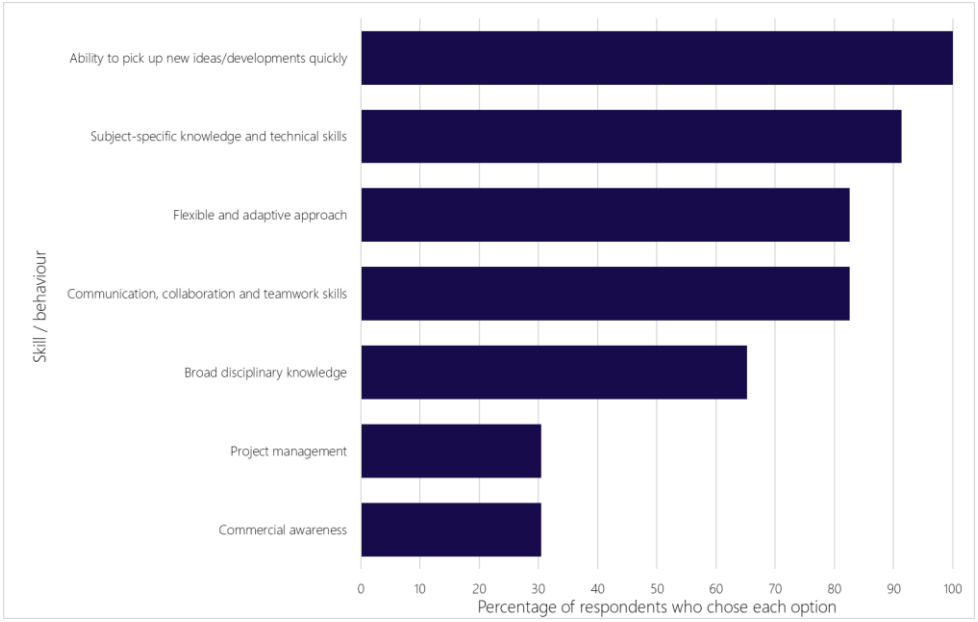
Of the top four expectations three are personal attributes that are distinct from the specific discipline or technical knowledge secured through doctoral training. They relate to the individual's ability to communicate, collaborate, be flexible and adaptable and pick up new ideas / developments quickly.

Interestingly, commercial awareness and project management skills were less commonly sought. This may reflect a view that these are addressed by the employer's internal training and development programmes.

"Commercial awareness and project management also useful but we train on the job to fit business requirements."

Figure 7: Skills and behaviours expected from PhD graduates when leaving university and starting employment (n=23)

"What are the key skills/experiences/attitudes you would want to see in a PhD graduate starting in your company?"



Additional comments emphasise expectations and desire in three areas: (i) core subject, discipline, and contextual knowledge, (ii) translational skills and commercial understanding and (iii) attitude and approach.

The free-text responses expand on these areas and contextualise views on expected skills from doctoral graduates as they move into employment. These responses broadly group into three areas (i) core subject, discipline and contextual knowledge, (ii) translational skills and commercial understanding and (iii) attitude and approach.

Core subject, discipline and contextual knowledge emerged strongly, critically this was commonly connected to the commercial / R&D requirement of the organisation.

"Solid understanding and practical experience in the scientific principles."

"Relevant subject matter expertise in order to start contributing commercial value as soon as possible."

"Specific and core technical skills in areas that we are actively involved in to support research and development programmes."

Alongside this, responses indicated a desire to see understanding and knowledge of the commercial or applied context for this, including progression through R&D into later product stages. We collectively describe these as "translational skills and commercial understanding". There is a degree of inconsistency between the response in figure 7 (commercial awareness) and the extent to which these appear in free text comments. We note that the phrase "appreciation of" is used several times in these responses and is useful in qualifying the expectations. These are areas that could be developed with industry partners as part of the CDT training programme and placements with a focus on appreciation of issues relating to progression from R&D into production environments.

"Ability to consider wider applications and exploitation of the technology domain. Appreciation of the wider product lifecycle requirements and the engineering integration issues."

"The ability to transfer their academic skills and experience into practical research for eventual product development."

"Appreciation of fabrication techniques & limitations."

"Skills in fabrication and manufacturing are also preferable alongside knowledge of relevant testing regimes and awareness of the need for good measurement."

Attitude and approach: soft skills and personal attributes that combine to demonstrate this are important

The third area of comments we described as 'attitude and approach', and comments here very much align with the frequency of responses in figure 7. Experience of team-work, strong interpersonal skills and reporting as part of and to a team are highlighted.

"Drive for results."

"I want to see genuine enthusiasm and interest, coupled with integrity and commitment to work."

"Adaptability and attitude - because everything else can be taught."

"Curiosity and ability to apply significant knowledge to new and unfamilar areas."

"Keen to learn (we typically expect to train them in commercial awareness, project management etc), collaborative, proven problem-solving, curious about subjects outside their training area."

"Motivated to add their unique contribution to the assembled technical capability as a member of a high performing and highly qualified team."

2.3 Opportunities and challenges

The most pressing challenge in securing and retaining staff is a lack of specialist knowledge and skills, and for some there is a requirement to employ UK nationals

All respondents indicated experience at least one challenge in securing or retaining the right staff for their organisation (Figure 8). Two linked issues emerged as challenges identified by the majority of respondents:

- a lack of applicants with relevant specialist knowledge or skills (78% of respondents); and
- a lack of *UK nationals* in the applicant pool, which may reflect restrictions for employers working in defence or security-related contexts (65% of respondents).

The issue ranked 3rd relates to the applicants who can apply their knowledge to practical work situations, an issue consistent with responses in the previous section. Free-text comments augmented the information provided, and typically address the challenge of finding specific technical / discipline knowledge in combination with the application of these into industrial R&D contexts, for example:

- experimental planning and awareness of design for manufacture; or
- awareness of industrial applications / needs / technology development requirements

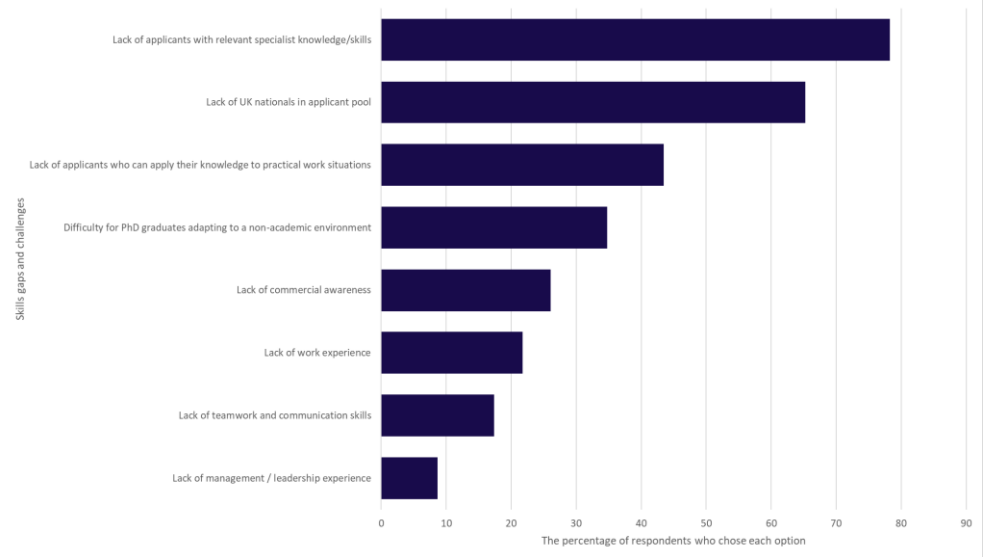
"(We see) a lack of awareness in the use of fabrication techniques to achieve performance outcomes for projects."

"The overarching issue right now is a massive lack of sufficiently qualified staff in the UK, this is further constrained by the need to employ UK nationals on several of our projects."

"(It can be) challenging to access the right people / skills at the right time to meet demands of multidisciplinary industrially focussed projects."

Figure 8: Key skills gaps and challenges organisations are experiencing in securing and retaining the right staff (n=23)

"Are there key skills gaps or challenges that you are experiencing in securing and/or retaining the right staff? Tick all that apply."



The impact of skills gaps on companies.

"How are these gaps or challenges impacting on the company?"

The survey asked how skills gaps identified in the previous question were perceived to be impacting on the company. Their free-text responses augmented the responses shown in figure 8 above and broadly group into three types of impact:

- delays incurred in recruiting and finding staff with the right mix of skills and aptitude;
- additional training or development being required in house; and
- consequential impacts for the business in terms of progression of product or technology development, or capacity limiting the ability to take on new / expanded work.

Securing the right technical skills is frequently cited, with consequential impacts in terms of delays and the requirement for additional training to compensate. For some participants this has meant a need to recruit international candidates, and with noted delays and expense through the Visa requirements. This is also noted to raise security issues for some participants / situations.

Some specific skills were identified as having perceived shortages, for example RF antenna engineering and theoreticians in electromagnetics.

"When we need to recruit competent technical experts, it can take a long time to find the right candidate."

"It reduces the pool of acceptable/suitable candidates and adds a high burden to train the required skills and behaviours. It also means that we are typically selecting non-UK applicants due to the deeper breadth of training in US and EU in some cases."

The comments also point to skills gaps driving a need for additional training and development for individuals, in some cases as a systematic way of working for that organisation (or area of the organisation). This is noted to create a heavy burden for some employers. Some comments reference training support for basic engineering principles or error analysis / checking.

"(We have had to) adopt a business case of teaching less experienced engineers (graduate level) on the job. There is an inherent learning curve associated with this."

A theme which appears throughout the survey is the need for strong technical skills to be found in combination with attitude, aptitude and awareness that employers are seeking for more commercial R&D environments. This re-occurs in comments here:

"We have an ongoing challenge with identifying and securing the right people with the right attitude. Skillsets are important but the right attitude will lead to growth and more opportunities."

"We see candidates with good technical skills, but cannot employ them as they are not a good fit for the collaborative / commercial environment of the industrial projects."

The consequences of skills gap also impact on respondents' approach to external collaborators or services, including collaborative R&D with universities and through consultancy. For technology development the landscape of generally short-term and intermittent funding for projects was noted to make collaborative progress on longer-term technology development difficult – the retention of key skills is difficult to sustain.

Diversity: the challenges in recruiting postdoctoral graduates mirror the wider situation for engineering / technology.

"What are the diversity (EDI) challenges in your recruitment strategy for postdoctoral graduates?"

Diversity in post-doctoral studies is currently receiving significant consideration as part of the wider set of issues around research culture. For example, for UK nationals those studying at doctoral level are notably less diverse than the equivalent undergraduate cohorts in the same disciplines.[1] This diversity gap tends to increase with progression in terms of (academic) research careers. The CDT may wish to explore how diversity between UG study (in relevant disciplines), and the national PGR cohort in relevant areas changes. Are there interventions that can address the diversity gap between the UG cohort and PGR cohort?

There is some evidence, for example the work by the Royal Society of Chemistry that indicates this exists within industrial contexts.

The survey asked about the diversity (EDI) challenges in employer's recruitment strategies for postdoctoral graduates. About half of the respondents identified specific challenges relating to diversity in recruitment: particularly gender, but also ethnicity and neuro-diversity. Where individual respondents indicated diversity related challenges, these typically reflected the issue prevalent more widely in their sector / discipline (and beyond doctoral-level recruitment). A lack of female applicants was noted by several respondents as a specific issue for diversity.

Responses were however mixed, some organisations indicated significant actions in this area (including company-wide policies, monitoring and support interventions, including early-stage engagement at school or college level). Others indicated no specific concerns relating to diversity, focusing on the specific skills and aptitude of the individual applicant. This may reflect their view of the extent to which they can influence this as an employer.

"(The challenges are) huge. We actively try and pursue any option to increase our diversity."

"We do not see enough female applicants. We are fully inclusive as an employer but just do not see a proportionate number of female applicants for jobs."

"We can only recruit the people who apply: finding a diverse pool of suitably-trained candidates is often very difficult. The need to recruit UK nationals in many posts exacerbates the issue."

[1] Various studies point to this trend, with particular issues for sex and ethnicity in UK nationals, progressing from undergraduate study to doctoral study and beyond. Reports include Royal Society (Joice & Tetlow, 2020, "Baselines for Improving STEM Participation: Ethnicity STEM data for students and academic staff in higher education 2007/08 to 2018/19.") and the Royal Society of Chemistry (2022) "Missing Elements Racial and ethnic inequalities in the chemical sciences".

Around half of the respondents cite specific interventions aimed at increasing diversity, including engagement with universities. We are aware of some CDTs developing approaches to improve the diversity in their cohort, including studentships ringfenced for certain underrepresented groups.

A recommendation is to explore, with employers, how the CDT might incorporate actions that actively encourage and facilitate improved diversity in the CDT's cohort of PGRs. For example, paid summer under-graduate placements for 'research', as part of the recruitment plan for the CDT. These might be in the university or with relevant employers, that actively seek to address under-representation in PGR study. Considering the evidence from employers, and the wider evidence base on PGR diversity, specific areas to target might be:

- UK nationals from under-represented ethnic groups in PGR study and wider sector; and
- female under-representation in the PGR study in the discipline and sector.

"HEI's could promote our strategy and openness to a more diverse work force."

"(We are undertaking) more engagement pre-university to encourage non-male, ethnically diverse students to pursue STEM careers in industry."

2.4 Training and Development

Encouraging growth of scientific knowledge and soft skill development in your employees: individual training and development plans feature strongly

"How do you encourage growth of scientific knowledge and soft skill development in your employees?"

Most responses indicate individual development and training plans are used, with expectation for continual development through CPD, conferences, networking and development experiences. Development led by the individual is expected in some cases.

Other examples of approaches cited include:

"We encourage staff to provide clear instructions with measurable results."

"We encourage them to ask questions and challenge the norm."

"Close interaction with academic partners, plus access to continuous improvement opportunities provided by the company."

"Through combination of formal and experiential learning, covering technical and non-technical skills as identified."

"Through the presentation of experimental results to the wider company audience."

Internal training appears as the lead source, supplemented by externally sourced

"What training is required for your existing staff to upskill and where will you source this training?"

provision on an occasional or as required basis.

From the qualitative comments, training is predominantly internal and organised around an individual's development needs (development plan). The responses suggest significant and well supported internal training provision in some of the responding organisations. Relatively few responses indicated consideration of departmental or job training being sourced externally at scale, but some examples were cited. Typically, external provision was sought on an occasional or 'as required' basis.

> ***"Each employee has his/her own development plan depending on their interest and career aims. We don't have specific department level needs."***
>
> ***"(We have a) varied portfolio of largely in-house training."***

These free-text comments provided some examples of the areas in which training was sought or provided. These included the following areas all of which are likely to resonate with the CDT requirements or interest:

- commercial and soft skills training;
- confidence in building relationships with external organisations;
- awareness of the link between science and funding;
- project management, including how to do projects on time and to budget; and
- specific technical training - coding, manufacturing, production.

> ***"We look for staff training to address specific challenges rather than generic training in a specific field."***
>
> ***"Mostly commercial and soft skills related. Some provided internally, others sourced externally."***
>
> ***"We have corporate training programs for soft and tech skills. We also run internal tech seminars and encourage staff to attend external training and educational events."***

Potential support to a CDT training programme: placements and other support to enhance commercial awareness are the top responses.

"If you were a project partner on a CDT, what training/experiences would you offer to the wider cohort to enhance the graduate education to prepare them for the job market outside of academia? (e.g. placements, scale-up masterclasses, other training they do not get in an academic environment)"

The survey explored what training or experiences could be offered by partners if they were collaborating in a future CDT. The question focused on what could be offered to the cohort to enhance their graduate education to prepare them for the job market outside of academia.

A thematic coding approach was used on the free text responses to group them, with the results shown in Figure 9. Answers to this question indicates a strong response in two areas:

- specific references to placements or other forms of project-based learning (around half of the responses indicated this option); and
- providing commercial or applied R&D experience and insights through other mechanisms (or undefined mechanisms).

Providing commercial or applied R&D experience and insights aligns strongly to the perceived skills gaps articulated earlier in the survey. This included the development of business cases for technological development, managing projects (including when to stop projects), choices in the commercial direction of projects, considerations for scale-up / manufacturing and intellectual property. Entrepreneurism was also referenced, in the context of venture-backed businesses and turning ideas into a business.

Although in earlier responses partners indicated substantive internal training provision, access to this as part of a CDT was not strongly indicated across all participants. This may be an area worthy of further discussion as some indicated opportunity here. For example, could PGRs engage in in-company training alongside employees as a way of developing industry networks and growing awareness of industrial contexts for R&D?

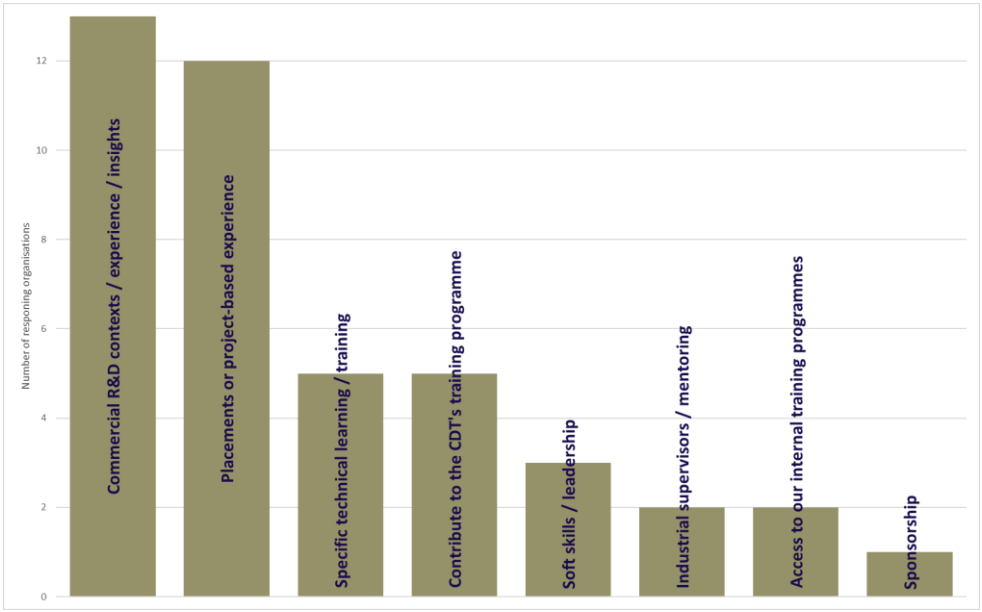
Training on specific technical or product elements also featured in responses, this included specific facilities or equipment, alongside company specific product design, process and manufacturing.

"Placements are the most likely. We offer access to our laboratories and people to gain direct industrial experience as required by the individual, with support from our people to assist or to act as industrial supervisors. We can also provide seminars and workshops for people requiring knowledge of the industrial world."

"The engagement and support from a large systems integrator will provide professional and industrial insights that would otherwise be unavailable to the students."

Figure 9: Potential contributions to a future CDT training programme, coding of free-text responses.

"If you were a project partner on a CDT, what training/experiences would you offer to the wider cohort to enhance the graduate education to prepare them for the job market outside of academia?"



2.5 Future needs

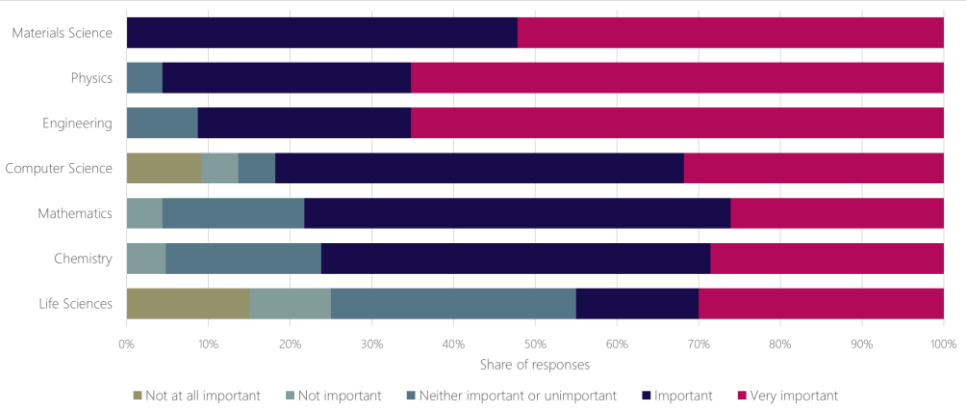
Future needs for doctoral level skills – understanding views on disciplines / areas

All respondents considered materials science to be an important area in which they foresee the need for doctoral level skills to increase over the next 10 years (Figure 10).

Respondents additionally reported via comments that data science, manufacturing, bio pharma and cross disciplinary areas are of importance.

Figure 10: Importance of areas where organisations foresee the need for doctoral level skills to increase in the next 10 years (n=23)

"What are the areas where you foresee the need for doctoral level skills to increase over the next 10 years, and how do you see the relative importance of these areas?"



The majority of organisations reported struggling with recruiting to positions that would benefit from doctoral skills, saw this demand increasing in the future, and thought ESPRC investment in this area would help

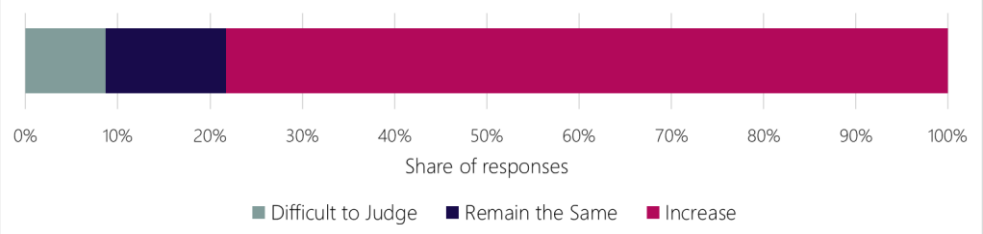
68% of participants reported struggling with recruiting to positions that would benefit from doctoral level graduates (n=19). A small number (10%) of respondents reported not struggling. The remainder indicated that they were not currently recruiting, a business case for recruitment needs to be made. In additional comments, the point was made that nationally there is insufficient expertise across all STEM subjects and at all qualification levels L3 to L8/9).

Crucially, 84% thought their recruitment needs for PhD graduates will benefit from ESPRC investment in doctoral training centres in this area (n=19).

The survey further asked about the perceived changes in the demand for recruitment candidates with doctoral skills over the next 5 years, Figure 11 indicates that this is expected to increase.

Figure 11: Perceived change in demand for recruitment candidates with doctoral skills, over 1-5 years.

"How do you see future demand for recruitment of candidates with doctoral level skills relating to metamaterials changing over the next 1-5 years?"



2.6 UK competitiveness

The UK is relatively well placed in metamaterials research, but more needs to be done to increase market uptake and exploitation.

What is your view on the overall state of the nation for UK R&D in metamaterials, and how competitive is it globally?

The survey asked for participants views on the overall state of the nation for UK R&D in metamaterials, and how competitive they perceive this to be globally. The responses were grouped into four areas:

- An assessment from about half of the respondents that UK R&D is well placed and relatively strong in metamaterials (although not in every area). China and the US are noted as strong(er) competitors in several comments, with the wider European landscape of universities also holding strength.
- A repeated concern that research exploitation, early market adoption and commercial outcomes from metamaterials is not matching that of the US and China. A need for more spin-outs to develop technologies was indicated as part of this overall view.
- Threats from difficulty in retaining graduates and a weakening UK position due to increased investment by competitors were noted in selected comments.
- New market and industry opportunities for metamaterials, in the food sector and in defence (an area indicated to have potential as an early adopter and beneficiary, and a partner that could help to drive industrial scale-up capability).[2]

"The UK has a competitive science base within its academic institutions but is, arguably, trailing other countries a little in investing in early market adoption."

"The UK is lagging behind both US, Europe and China on translation to enterprise value and industrial applications."

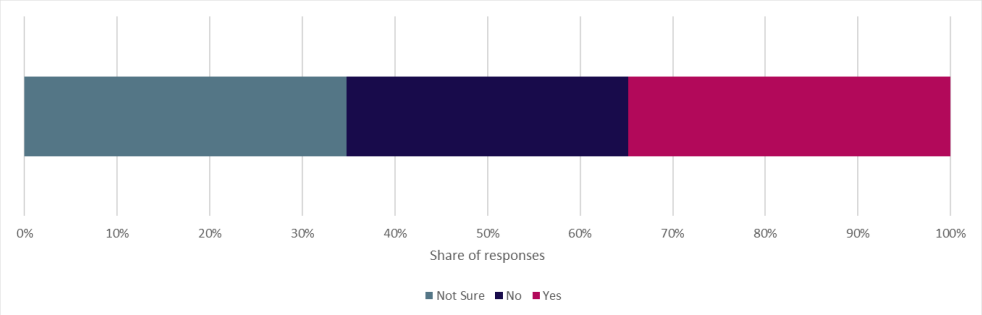
"On the R&D side UK is one of the leading sources of innovation and R&D and a lot of great science is being carried out."

"UK (academic) R&D strength is at risk; industrial take-up needs support to achieve competitiveness and to position UK for consequent advantage."

The survey subsequently asked about the movement of research into commercialisation. The response in Figure 12 indicates a diversity of views on this question.

Figure 12: Success of new technologies

"Are technologies and new ideas successfully moving from research into commercialisation?"



[2] A sector which also has a strong requirement for the recruitment of UK nationals into technical or R&D roles.

Key factors to increase the commercialisation of research in metamaterials.

What key factors might enable the increased commercialisation of research?

Free-text responses to this question provided a range of responses, these group into four areas:

- Access to technical and metrology tools, funding and facilities that support progression from research into development and scale-up, allowing early consideration of issues such as quality control and scale-able manufacture. This included access to de-risked materials and funding that supports support R&D at TRL4-6.
- Increasing the availability of skills for commercialisation from research, including IP management, industrial/academic collaboration and increasing the wider understanding of the consumer and business problems to solve.
- Continuing to develop and enhance industry engagement with academia but also the full supply chain where metamaterials offer potential. A key feature of this is to better connect researchers with the use case and industry partners best positioned against application areas with the best chances of success.

"Increased availability of skills and expertise to enable higher TRL development and implementation of the concepts."

"Integration with industry at the early stages of development. This means the complete supply chain, not just the end user."

"Finding the right use cases and solving industrial challenges where there is a strong pull from OEMs."

"Connecting the researchers with the industrial partners who are best able to commercialise."

"Early training within academia on better collaboration with industry."

Strong potential, underpinned by the underpinning research and existing supply chains, but concerns grow about the supporting infrastructure and skills for technology development and manufacture.

What is your view on the competitiveness of the UK's commercial landscape in metamaterials?

Although there was some divergence of views, the responses here echoed earlier comments and were largely consistent with these. The UK was perceived to have a good underpinning foundation in terms of the scientific and lower TRL research capability. But this view weakens as we start to look at higher TRL levels, commercialisation and exploitation. There are noted to be some successes, but this is qualified by the perception of a relative lack of success stories compared to other territories. Further up the development pathway, more concerns were expressed over, for example, a lack of production capacity, investment into growth for start-up businesses and support for scaleup into manufacturing.

"The outlook is good: the fundamental science has been well supported, but does need a plan to integrate with industry to sell the science."

"Entrepreneurial spirit in UK is improving and SME / innovation sector is strong (in general), but presently there are only limited examples and success stories for metamaterials (compared to competitors)."

"There is potential to grow into a major player, since many of the key supplementary and pre-requisite capabilities are available in the UK (e.g. strength in core sciences, conventional materials supply chains)."

Funding and support to improve networking and connectivity within the developing metamaterials landscape emerged as desired changes to support UK capabilities.

What government investments or interventions would you like to see to support innovative capability/global competitive advantage?

Funding and improved networking / connectivity for metamaterials research and commercialisation emerged as high frequency free-text comments to this question. Other comments addressed the talent pipeline, with particular focus on skills for the translation of research to industry, and the networking/connectivity of this area.

On funding, there was a focus on the need for additional funding that supports translation from research into industry and enables industrial partners to better access the skills and facilities held within the research base. This includes funding to bridge the gap from novel prototype to commercial demonstrators. This is understandable given the nature of the area and previous comments on the perceived position of the metamaterials area. One specific suggestion was that the UKMMN in future should look to incorporate budgets for steerable research to answer emergent industry pull for innovation.

"Supporting innovation from new technology such as metamaterials requires pre-competitive funding."

"Government backed support programs to pay for integration between academia and industry."

"Feasibility projects with academia and industry at this stage with mechanisms to access capital equipment at reasonable cost (low margin access)."

Improved networking / connectivity for metamaterials research and commercialisation covered a number of angles, including a perceived need for leadership at a national level to drive short term progress and long-term success. The need to raise industry awareness of the technology and potential applications was indicated and also cited in responses to other questions.

"It's difficult for one start-up to develop all the new tech and manufacturing capability on its own. Anything that could be done to connect start-ups to other active players would help reduce the risk."

Targeted funding into certain application areas was noted, the food sector has been identified previously as an application area (and was noted to be the largest manufacturing sector in the UK). Another comment suggested targeted investments into the maritime sector. The space sector was referenced in a third comment.

"Obviously supporting academia in keeping and expanding resources but also offer substantial more incentives to both academia and industry cooperating."

"Strategic alignment of technology development from academic R&D, via RTO's into industrial applications, and better funding opportunities to support / maintain successful collaborations in this area to ensure metamaterials can be developed for industrial application and performance in service."

3. Conclusions

An emerging area of opportunity for the UK, building on acknowledged strengths in the underpinning research

This work identifies that metamaterials is an area of emerging opportunity for the UK, with acknowledged strengths in the underpinning science. It identifies a continuing need to see this translated into a potentially wide range of commercial applications. Doctoral training will play an important part in this, but wider support from the UK's research and innovation funders is needed to support specific projects and (importantly) networking across R&D and supply chain organisations.

As an emerging area, there is a continuing need to connect the 'metamaterials' R&D teams in the university landscape and in industry. These should sit alongside measures to support the supply chain, including awareness of the potential for these new materials. The CDT plays an important role in supporting this networking, giving industry partners access to a wider range of current research and connections across sectors.

Current challenges in recruiting the right skills, and demand for doctoral level skills is expected to increase.

The participants are active collaborators with universities and significant employers of doctoral graduates and their associated skills. Physics, engineering and materials science disciplines are most commonly sought when employing doctoral-level graduates.

Skills at doctoral level are already found extensively within the organisations responding to the survey, in their R&D and development functions. Limiting skills gaps and challenges are evident, there are perceived challenges in recruiting the right staff to meet the technical skills needs of these employers currently, and the expectations are that the requirement for doctoral-skills will increase over the next five years.

The availability of the skills needed to support industrial exploitation, across many application areas and sectors, are of concern to the participating industry partners.

The added-value of centre-based doctoral training is recognised – for individual students and the industry partners.

The added value of CDT-based doctoral training is recognised by these employers. This added value is perceived to deliver benefit in terms of the enhanced skills and experience of individual students, and also in terms of the CDT providing industry partners with access to a wider range of research, relevant networks (academic and industry) and as pool of students (for potential recruitment).

Strong technical/subject skills are sought, but the importance of a wider set of awareness and competence in soft skills must not be overlooked.

The importance of strong technical skills in terms of the subject area, discipline and the technical aspects are noted when seeking to employ doctoral students.

But what also emerges strongly is the importance of a wider set of knowledge, competencies and behaviours critical to successful progression into industrial R&D employment.

These include awareness of the wider landscape for their technical knowledge, and appreciation of the commercial application and developmental landscape for research moving into development and towards scale-up and manufacturing.

Alongside this, significant importance is placed on strong competencies in soft skills. These are skills that combine to give the 'attitude and approach' sought by employers, team-working, interpersonal skills, curiosity and the flexibility / adaptability to pick-up new ideas or developments quickly. They represent behaviours and characteristics strongly

associated with being able to successfully work in a high performing technical R&D environment.

Opportunities to increase the engagement of industry partners in a future CDT training programme

There is potential to enhance the benefits of centre-based training to further engagement with industry partners. This includes widening the pool of employers providing technical placement opportunities to enhance the availability of these, connecting to in-house company training provision (particularly to enhance awareness and appreciation of commercial drivers and progression from development to scale-up / manufacturing) and drawing on their expertise to provide awareness and appreciation of some of the commercial environments particularly the issues in moving from research into development and scale up or manufacturing.

Evident challenges in diversity within employers and recruitment.

Other reports and evidence indicate that diversity in the sector and relevant academic disciplines is an issue, particularly for gender, and also ethnicity. The latter, at the level of doctoral study, is noted to be particularly acute for UK nationals (an issue which can be masked by international students studying at doctoral level). National statistics indicate that diversity at doctoral study tends to reduce compared to the undergraduate populations in the first-degree disciplines. Whilst acknowledging that there is inevitably limited scope for a single employer or CDT to significantly impact on this, a future centre for doctoral training should consider what measures may be appropriate to address this and encourage individuals from under-represented groups into post-graduate research (PGR) study.

We recommend that the future planning for a CDT in this area explores how working with the industry partners, they can develop initiatives and measures to explicitly increase diversity in the intake into PGR training. This might include for instance, industry connected vacation scholarships for undergraduates from underrepresented groups, explicitly designed to provide research experience and to encourage progression into the PGR study.

3.1 Recommendations

Recommendations for consideration in the development of doctoral training for metamaterials.

Drawing from this research and the evidence gathered, we make a number of recommendations for the future design and approach to CDT training. These are provided as recommendations for consideration. Some may require further discussion and engagement with academic and industry partners to identify appropriate mechanisms and resourcing.

Recommendation

How can a future CDT enhance existing benefits to industrial partners?

The report identifies how industry partners perceive the additional benefits of working with centre-based doctoral training, particularly the access to the wider body of research. The work also identifies that for metamaterials there are perceived issues in terms of supporting industrial networking and the development of application areas (including awareness in the wider supply chain). In designing a future CDT can these wider networking needs be incorporated more strongly, engaging active partners and a wider group of companies in communications, networking and activities (e.g. placements)?

Recommendation

Actively develop the pool of organisations hosting doctoral placements

The findings indicate that there may be scope to expand the range of relevant organisations hosting doctoral placements. This is a mechanism available to a wider pool of organisations (compared to those able to fund or co-fund doctoral training).

An enhanced placements programme has benefits for individual students (commercial experience, contexts and awareness) and the wider networking, dissemination and engagement functions of the CDT.

Recommendation

Develop and enhance the training programme supporting wider skills in doctoral students

The report provides a clear indication of the importance of a wider set of skills and competencies, beyond the specific technical and disciplinary knowledge of the doctoral student. The development of a supporting training and experience-based programme to ensure these are addressed is recommended. Areas to focus on include:

- the competencies and requirements of working in high performing industrial R&D teams, including appreciation of commercial and product development issues (e.g. scale-up, manufacturing)
- understanding of the wider research and commercial landscape for metamaterials technologies, exploitation and applications; and
- the soft skills and competencies that support successful progression into industry-based R&D teams.

Recommendation

Explore opportunities to draw from and to incorporate company in-house training.

Several companies report in-house training programmes that support new entrants and in some cases explicitly address areas of perceived skills or knowledge gaps. In some cases these align to areas where skills and knowledge are sought in doctoral students, for example understanding of commercial contexts, scale-up or project management / reporting. We recommend that further discussions with industry partners are held to explore how synergies between the CDT training programme, skills development needs and existing industry support for their employees might realise greater synergies.

This may be accomplished through a range of measures, including formal training, site visits, placements and networking between CDT students and early career R&D employees in the industry partners.

Recommendation

Design in approaches, working with industry partners, to encourage and facilitate greater diversity in recruitment to the CDT and PGR study

The design of a future CDT should carefully consider how measures to encourage and facilitate an improved uptake of PGR studentships by individuals from under-represented groups can be supported. The report suggests that this should focus on gender and ethnicity, but should also consider this in the context of UK nationals entering PGR study.

Measures to support this might include the development of undergraduate 'vacation scholarships' linked to experience of metamaterials research with a strong industry engagement element (including hosting).

Appendix A. Summary of the survey questions

Table A. High-level summary of final survey questions.

Question	Response Format
About your organisation	
Please enter the name of your organisation.	Free text box
Which of the following best describes your organisation? Tick all that apply. • Industry • Government agency • Public sector research establishment / National laboratory / RTO	Multiple choice, with write in option
Please indicate the overall size of your organisation (UK and global) based on employee numbers	Multiple choice
Which of the following best describes your organisation? • Headquartered within the UK, with a presence in other countries. • Headquartered outside the UK with a UK presence. • Based wholly within one region or nation of the UK (e.g., West Midlands, Wales) • Based within several regions or nations of the UK (including Wales and / or Scotland)	Multiple choice
Please select the region or nation of the UK your organisation is based.	Multiple choice
Please select the regions or nations of the UK your organisation is based.	Multiple choice
Are you responding on behalf of your organisation or a team/department within it?	Multiple choice, with write in option
How many staff are employed within your department or team?	Free text box
Which of the following best characterise your role and the areas for which you are able to respond? • Organisation-level leaderships (e.g., CEO, CTO) • R&D leadership or senior management • Research scientist • Product development scientist (existing products) • Head or leadership role in a specific technical function of your organisation • Project management	Multiple choice, with write in option and comments box
Working with universities	
How often do you work with universities and doctoral students in each of the following areas? • We collaborate with universities in research projects funded by public funding organisations and schemes (including for example UKRI (e.g. UK research councils such as EPSRC and Innovate UK) and the Defence and Security Accelerator) • We contract research projects funded by my organisation. • We sponsor (in whole or in part) Masters/other sub-doctoral students at universities. • We sponsor (in whole or in part) PhD / doctoral students at universities. • We host placements for doctoral (PhD) level students. • We use the equipment and facilities at universities. • We have academic advisors on our Boards or advisory groups. • We are involved in other university-based advisory groups or their industry groups.	Likert scale

• We use academics as consultants to our business/organisation. • We are involved in the UK Metamaterials Network.	
What areas are you most interested in recruiting into?	Likert scale
What specific benefits would you wish to secure as an organisation from collaborating with universities through centres for doctoral level training? Tick all that apply. • Increased visibility of your organisation(s) • CPD opportunities for staff to engage with students. • CPD opportunities for staff to engage in seminars, career events, conferences, and teaching. • Direct contact with students and academics • Opportunities to pursue research that would otherwise be impossible	Multiple choice, with write in option and comments box
Doctoral training and recruitment of skills	
Please consider the potential reasons for involvement and interest in doctoral training. How important are each of the below to your organisation? • To maintain an existing relationship with the university and key academics • To develop a new relationship with the university and key academics • To enable a watching brief on the latest developments in this area • As part of our wider portfolio of work with the university / universities • To explore areas of potentially important R&D for the business / organisation • To recruit individuals from doctoral training into the business / organisation • To influence the areas of research being explored	Likert scale
What added value do/would you gain from recruiting doctoral graduates out of a cohort-based CDT rather than from lone-scholar projects?	Free text box
To what extent do you explicitly recruit people with a doctorate degree?	Multiple choice, with write in option
How many of your current employees have a doctorate? Please use the text box below to suggest this as a percentage. Please state if you are answering for your organisation as a whole, or for a specific area in your response.	Free text box
If you are employing doctoral level graduates, which scientific backgrounds are typically sought? Tick all that apply. • Chemistry • Computer Science • Engineering • Life Sciences • Materials Science • Mathematics • Physics	Multiple choice, with write in option
What skills or behaviours would you expect from PhD graduates when leaving university to start employment? Tick all that apply. • Broad disciplinary knowledge • Subject-specific knowledge and technical skills • Ability to pick up new ideas/developments quickly. • Communication, collaboration, and teamwork skills • Flexible and adaptive approach • Commercial awareness • Project management	Multiple choice, with write in option

What are the Key skills/experiences/attitudes you would want to see in a PhD graduate starting in your company - and why?	Free text box
Opportunities and challenges	
Are there key skills gaps or challenges that you are experiencing in securing and/or retaining the right staff? Tick all that apply. • Lack of UK nationals in applicant pool • Lack of applicants with relevant specialist knowledge/skills • Lack of applicants who can apply their knowledge to practical work situations. • Difficulty for PhD graduates adapting to a non-academic environment. • Lack of teamwork and communication skills • Lack of work experience • Lack of commercial awareness • Lack of management / leadership experience • No skills gaps / challenges experienced	Multiple choice, with write in option and comments box
How are these gaps or challenges impacting on the company?	Free text box
What are the diversity (EDI) challenges in your recruitment strategy for postdoctoral graduates?	Free text box
What are your organisation's strategies to address EDI challenges at recruitment level that Higher Education Institutions should adopt?	Free text box
Training and development	
How do you encourage growth of scientific knowledge and soft skill development in your employees?	Free text box
What training is required for your existing staff to upskill and where will you source this training?	Free text box
If you were a project partner on a CDT, what training/experiences would you offer to the wider cohort to enhance the graduate education to prepare them for the job market outside of academia? (e.g., placements, scale-up masterclasses, other training they do not get in an academic environment)	Free text box
Future needs	
What are the areas where you foresee the need for doctoral level skills to increase over the next 10 years, and how do you see the relative importance of these areas? • Chemistry • Computer Science • Engineering • Life Sciences • Materials Science • Mathematics • Physics	Likert scale
Do you struggle to recruit to positions that would benefit from doctoral level graduates in this area?	Multiple choice, with write in option
Do you think your recruitment needs for PhD graduates will benefit from EPSRC investment in doctoral training centres in this area?	Multiple choice, with write in option
How do you see future demand for recruitment of candidates with doctoral level skills relating to metamaterials changing over the next 1-5 years?	Multiple choice, with write in option
UK competitiveness	

What is your view on the overall state of the nation for UK R&D in metamaterials, and how competitive is it globally?	Free text box
Are technologies and new ideas successfully moving from research into commercialisation?	Multiple choice
What key factors might enable the increased commercialisation of research?	Free text box
What is your view on the competitiveness of the UK's commercial landscape in metamaterials?	Free text box
What government investments or interventions would you like to see to support innovative capability/global competitive advantage?	Free text box
Optional Contact	
Would you like to be contacted for permission to be quoted in the final report? If you tick "no", any quotes gathered via this survey submission will be anonymised.	Multiple choice

Appendix B. Overview of the survey participants

21 unique organisations contributed to this research

There were 23 responses from 21 organisations. See Table B for a list of the participating organisations:

Table B. Organisations who participated in the research

Organisation Name	Organisation Name
Advanced Material Development Ltd	MBDA UK
Atlas Elektronik UK	Merck KGaA
BAE Systems	Merck Performance Materials Ltd
BT Group PLC	Meta Materials Inc
Chelton	Oxford Instruments Plasma Technology
Dstl	PepsiCo
Electrosciences Ltd	QinetiQ Ltd
Flann Microwave Ltd	Snap Inc.
High Value Manufacturing Catapult	Technical Composite Systems
Leonardo UK	TWI Ltd
M Ventures	

87% of participating organisations were industry based

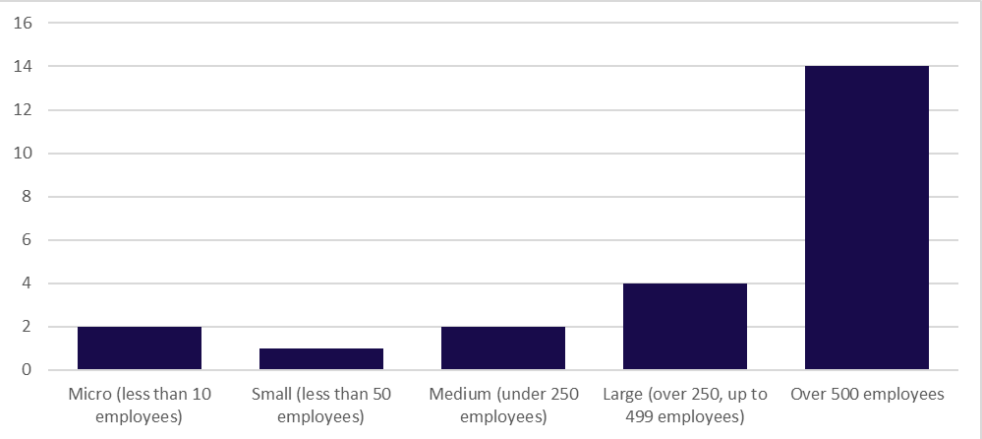
The majority (87%, 20 out of 23) of the responding organisations can be best described as private industry organisations, while the remainder can be considered as a public sector research establishment / National laboratory or RTO.

60% of the organisations had over 500 employees

60% of the organisations who participated in this research had over 500 employees. 12% of the respondents were from small or micro-organisations. Figure A visualises the distribution in these organisations, grouped by organisation size.

Figure A: Respondents grouped by organisation size

"Please indicate the overall size of your organisation (UK and global) based on employee numbers."

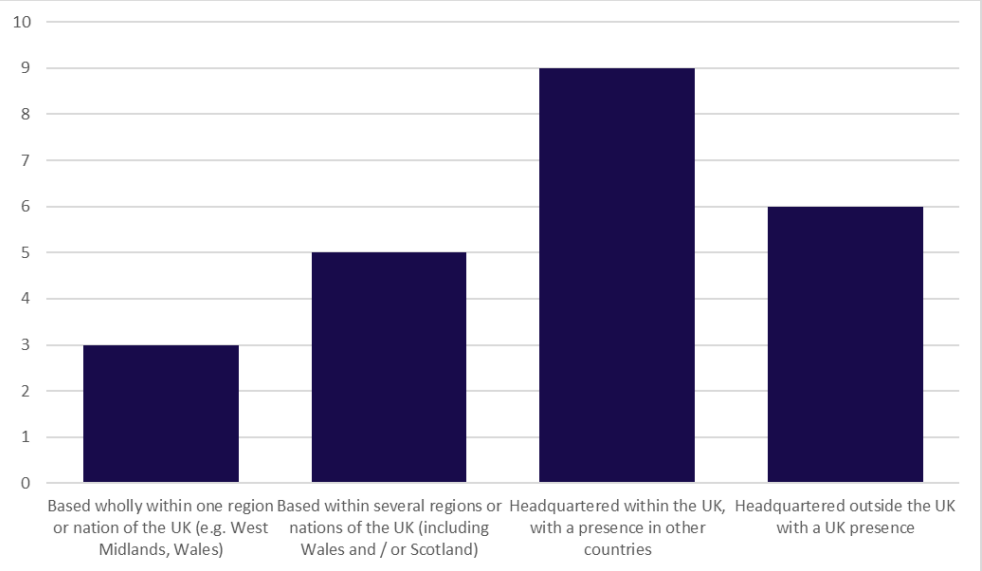


The majority of organisations are headquartered within the UK with a presence in other countries

Of the organisations that participated, 40% (9 of 23) were headquartered within the UK, with a presence in other countries, 26% (6 of 23) were headquartered outside of the UK with a UK presence, the remaining 35% (8 of 23) were based wholly within one region 13% (3) or within several regions and nations of the UK 22% (5 of 23). See Figure B.

Figure B: Respondents organisation Headquarter location.

"Which of the following best describes your organisation?"



Organisations have locations across Great Britain

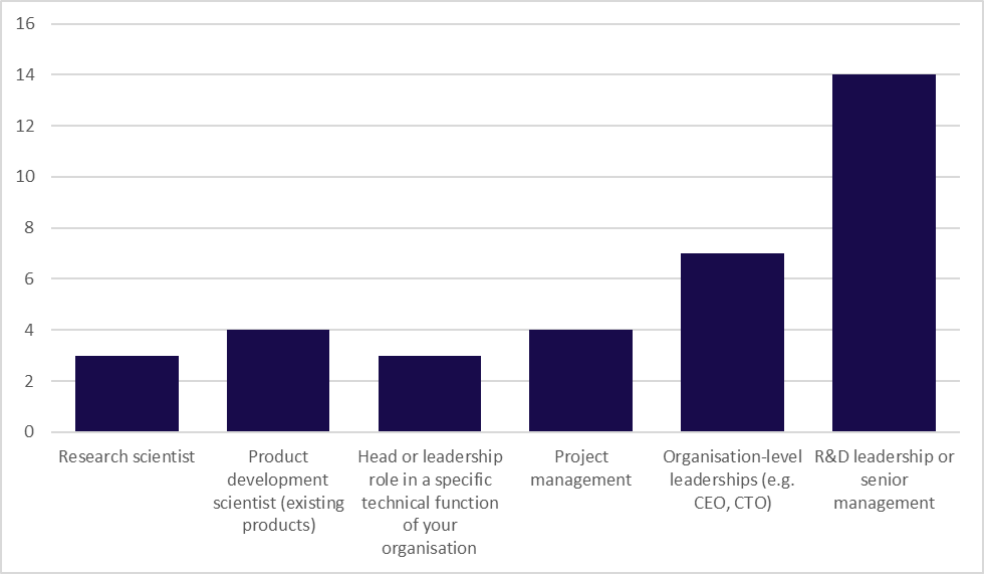
The participating organisations had locations across regions and devolved nations in the UK including: East, North-East, North-West, South-East, South-West, West Midlands, Scotland, and Wales.

Respondents held senior roles in their organisations

Respondents hold a variety of senior roles within their organisations, from organisation level leadership such as CEO or CTO, to R&D leadership or senior management, project management, product development scientists, research scientists, and the head of specific technical organisational functions (See Figure C).

Figure C. Roles of respondents within their organisations

"Which of the following best characterise your role and the areas for which you are able to respond?"



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