The physics graduate "skills gap" – what it is and how to address it

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Introduction

Physics graduates are highly employable[2,3], and a lower fraction take up non-graduate roles than the national average[4,5] (see box), but there is a perception that they do not possess the range of technical and 'employability' skills that industry requires[6]. There is also a national shortage in the *number* of skilled workers, exacerbated by the lack of diversity in students studying STEM[7]. Both themes are addressed in the UK Industrial Strategy[8]. In this report, we examine the gap in physics graduates' range of industry-valued skills, and what universities and industry can do to address it.

Graduates in work & further study (Graduate Outcomes 2017/18, 15 months after graduation, pub. June 2020):
Physical Sciences 89%
cf. Mathematical Sciences 89%; Computer Science 90%; Engineering & Technology 91%;
cf. All sciences 91%; All graduates 89%

Recent graduates working in non-graduate roles (2016/17 DLHE data):
physics graduates: 20% (SEPnet figure: 21%); all graduates 26%

Unemployment (Graduate Outcomes data 2017/18):
physics graduates 5%; all graduates 5%

What does the skills gap look like?

The 2011 sector-wide study "Employers' perceptions of the employability skills of new graduates"[9] identified that "employers expect graduates to have technical and discipline competences from their degrees but require graduates also to demonstrate a range of broader skills and attributes that include team-working, communication, leadership, critical thinking, problem solving and managerial abilities." In a physics-specific study by the HEA[10,11], new graduates similarly report non-discipline-specific attributes as more important once they begin work (Figure 1). A very similar picture is reported by European Natural Science postdocs[12]. The non-physics-specific report "Skills Shortages in the UK 2019/20"[13] provides a reminder that core technical skills are still important; the section "What makes positions

[1] SEPnet – the South East Physics Network – is a network of nine universities (Hertfordshire, Kent, Open University, QMUL, Portsmouth, RHUL, Southampton, Surrey, Sussex) in the South East of England, working together to deliver excellence in physics. http://www.sepnet.ac.uk/

[2] Destinations of Leavers of Higher Education (2016/17), as surveyed 6 months after graduation https://www.hesa.ac.uk/data-and-analysis/publications/destinations-2016-17 , Table E

[3] Graduate Outcomes (2017/18), as surveyed 15 months after graduation https://www.hesa.ac.uk/data-and-analysis/graduates/releases, https://www.hesa.ac.uk/data-and-analysis/sb257/figure-10

[4] The 2016 Wakeham Review of STEM Degree Provision and Graduate Employability (Table 2 & 5) found that Physics and Astronomy graduates had an above STEM-average level of unemployment (see likewise the 2016/17 DLHE survey cited on Page 1 of this report), but had better than STEM-average outcomes for securing "graduate" roles and higher salaries. Most employment measures also correlate with average entry tariff, in ways that might be expected. https://www.gov.uk/government/publications/stem-degree-provision-and-graduate-employability-wakeham-review

[5] SEPnet figure compiled in SEPnet report. VB 8/2/19.

[6] §5.17 https://www.gov.uk/government/publications/stem-degree-provision-and-graduate-employability-wakeham-review

[7] See Nicola Turner's NCUB blog in connection with delivering the UK Industrial Strategy: https://www.ncub.co.uk/blog/closing-the-skills-and-talent-gap-to-deliver-the-industrial-strategy

[8] UK Skills Mismatch in 2030, Industrial Strategy Council, 2019 https://industrialstrategycouncil.org/sites/default/files/UK%20Skills%20Mismatch%202030%20-%20Research%20Paper.pdf

[9] "Employers' perceptions of the employability skills of new graduates" Research commissioned by the Edge Foundation, Kevin Lowden, Stuart Hall, Dr Dely Elliot and Jon Lewin; University of Glasgow 2011 http://eprints.gla.ac.uk/54996/

[10] Higher Education Academy; now part of Advance HE https://www.advance-he.ac.uk/

[11] "Skills required by new physics graduates and their development in degree programmes", Steve Hanson and Tina Overton; HEA PSC 2010 https://hydra.hull.ac.uk/resources/hull:4547

[12] Ålund, M., Emery, N., Jarrett, B.J.M. *et al.* "Academic ecosystems must evolve to support a sustainable postdoc workforce". *Nat Ecol Evol* (2020). https://doi.org/10.1038/s41559-020-1178-6

[13] C. Ball "Skills shortages in the UK 2019/20", Prospects, https://luminate.prospects.ac.uk/skills-shortages-in-the-uk

hard to fill" identifies technical/practical "specialist skills or knowledge" as the dominant skills deficit, cited around 70% of the time, in contrast to the most-cited "soft" skill – "Ability to manage own time and prioritise own tasks" – which is cited around 40% of the time. SEPnet has an Employer Advisory Group comprising ~12 industry partners, as well as an employer network of over 200 contacts, and co-organises an annual workshop with WRIPA[14] on embedding employability in the physics curriculum. Employers' routinely signal a desire to see physics graduates improve/develop business/commercial skills and awareness, programming, communication/presentation, practical/technical skills, and modelling and analysis[15].

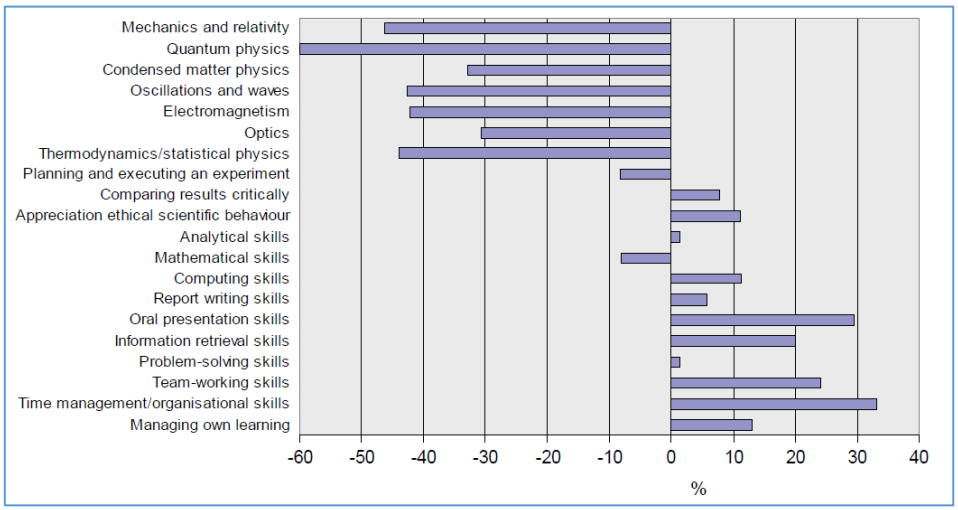

Figure 1. Development deficit (as percentage reflecting relative importance) reported by physics graduates just 2-3 years after graduation. Broadly speaking, categories trending to the left of zero have decreased in importance since graduation, whereas categories to the right have increased in importance. Notably, most subject-specific knowledge on which graduates were examined falls into the former, while the skills reportedly valued by employers are reflected in the latter.
Source: "Skills required by new physics graduates and their development in degree programmes", 2010, Fig. 11, Reproduced with permission © Higher Education Academy Physical Science Centre – now Advance HE

These varied characterisations of the skills gap remind us that it can be difficult to identify what is at the heart of the skills gap; seeking to *eliminate* it may be a chimeric pursuit, but *reducing* it is important for the career prospects of graduates and for a future positive relationship between industry/business and universities.

Skills gap or expectations gap?

Could the "skills gap" equally be an "expectations gap"? Are industry expectations too diverse to be fulfilled in 3-4 years of undergraduate physics training? The Wakeham report recognised that requirements for practical skills and knowledge will change over a graduate's career, requiring them to re-invent and upskill themselves as change is endemic and accelerating[16,17]. The crucial challenge is for universities and employers to ensure a close and ongoing engagement to minimise and respond to skills or expectations gaps as they appear. The annual SEPnet/WRIPA Workshop on Employability in the Curriculum[18] is one forum set up with this purpose. The challenge is made even more acute by the economic turmoil triggered by the Covid-19 pandemic; with most economic indicators in steep decline, many commentators are anticipating a recession that will result in there being many fewer opportunities for graduates in 2020, with impacts lasting into 2021 or even beyond[19]. Now more than ever, universities and business need to work together, in ways that have been found to be effective, to reduce the physics graduate skills gap.

[14] White Rose Industrial Physics Academy https://wripa.ac.uk/
[15] SEPnet records: Industry Survey Feedback 2018/VB 4.9.18
[16] https://www.gov.uk/government/publications/stem-degree-provision-and-graduate-employability-wakeham-review
[17] See also Andy Haldane (Chair, Industrial Strategy Council), "Worsening UK skills gap will hold the country back" 24 Oct 2019 Financial Times https://www.ft.com/content/96e43c16-f592-11e9-bbe1-4db3476c5ff0
[18] http://www.sepnet.ac.uk/wripa-sepnet-joint-workshop-physics-industry-collaboration-aligning-student-skills-with-local-economic-needs-25-july-iop-london/
[19] Tristram Hooley, "Redefining the employability agenda in the age of Covid-19", HEPI blog 11/4/2020 https://www.hepi.ac.uk/2020/04/11/redefining-the-employability-agenda-in-the-age-of-covid-19/

Higher-Education-sector reports suggest that "Demand for STEM-related occupations is projected to grow at double the rate of other sectors"[20] and that there is already a deficit in the number of skilled graduates: in 2016, 440,000 new professional jobs were created, yet there were only 316,690 first-degree UK-based graduates, double the recruitment gap of 2015, and expected to increase alongside demand for higher-level and new skills[21]. The UK Industrial Strategy Council[22] presented OECD figures which anticipate physics experiencing the sixth highest skills shortage by 2030, alongside Engineering, Mechanics and Technology. The future view of these reports provide another reminder alongside the Wakeham report that the "skills gap" is not a transient phenomenon of the early 21st century, but will evolve as industry's needs change; the goal-posts will move, and the university-industry partnership must develop graduates with the flexibility to acquire new knowledge and the ability to embrace new technology and adapt to rapidly changing industries.

Ultimately, at the heart of these debates is a discussion of what kind(s) of education physics graduates should receive, and the role of industry in contributing materially, not just vocally, to industry-relevant training. The debate is not unique to the UK; it arises also in the USA[23] and Australia[24] where the point has been made that STEM graduates might be underprepared for the workplace *if they do not also have industry experience*, echoing the Wakeham report where the importance of formal or informal work experience was a strong theme, leading to a recommendation that ideally all students would benefit from work experience during their degree. A common element of most undergraduates' physics degrees is the IOP's requirements for accreditation. The IOP is currently reviewing this framework to include a stronger focus on embedding employability skills within the curriculum.

Positive steps

Research by SEPnet's Employer Engagement programme[25] suggest that the *physics* skills/expectations gap is mainly concerned with a lack of work-readiness and some transferable skills, with a desire for greater software knowledge coming closest to a discipline-specific skill. Lack of commercial awareness is often cited. It is difficult to see where physics students could develop some of the skills that industry seeks other than directly in industry, which is something that placements facilitate. Relatedly, graduate-employer surveys[26] indicate that 30-40% of companies will only recruit graduates with work experience.

All SEPnet universities offer eight-week, employer-funded or joint-funded paid summer placements[27] which are taken up by ~75 students per year[28] in the summer following their 2nd (and for MPhys students also their 3rd) year of study. Placements are provided by a range of employers across a number of sectors, and commonly provide students with the opportunity to develop industry-based experience in programming, data analysis and experimental/research work (Figure 2), complementing their academic studies. For many students, the process of applying for a SEPnet placement is their first time plying their trade as a physicist, so the application process itself builds skills and experience. Applications are made direct to the companies, on a competitive basis, with a median of

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T. Wilson, J. Cockett, D. Papoutsaki, H. Takala, "Getting back to work", Institute for Employment Studies, Apr 2020 blog, https://www.employment-studies.co.uk/resource/getting-back-work-0?
"Recruitment is on hold': the students graduating into the Covid-19 recession" Guardian 10/4/2020 https://www.theguardian.com/education/2020/apr/10/recruitment-is-on-hold-the-students-graduating-into-the-covid-19-recession

[20] https://www.ncub.co.uk/blog/closing-the-skills-and-talent-gap-to-deliver-the-industrial-strategy
[21] The UUK 2018 report "Solving Future Skills Challenges" https://www.universitiesuk.ac.uk/policy-and-analysis/reports/Pages/solving-future-skills-challenges.aspx
[22] UK Skills Mismatch in 2030, Industrial Strategy Council, 2019 https://industrialstrategycouncil.org/sites/default/files/UK%20Skills%20Mismatch%202030%20-%20Research%20Paper.pdf
[23] "Will employability make universities redundant?" Paul Basken, Times Higher Education 23 Jan 2020, p30-35 https://www.timeshighereducation.com/features/will-us-universities-be-made-redundant-employability-agenda
[24] https://www.dailymail.co.uk/news/article-6049613/Students-graduating-sought-STEM-degrees-worst-chances-landing-right-job.html
[25] SEPnet records: Industry Survey Feedback 2018/VB 4.9.18
[26] The Graduate Market in 2018, p. 24. https://www.highfliers.co.uk/download/2018/graduate_market/GMReport18.pdf ; also The Graduate Market in 2020, p. 23 https://www.highfliers.co.uk/download/2020/graduate_market/GM20Report.pdf
[27] http://www.sepnet.ac.uk/students-employers/for-students/sepnet-summer-placement-scheme-information-students/
[28] 2018: 74, 2019: 74. Source: SEPnet records (VB, 10.12.19)

~13 applications per placement[29]. SEPnet's structured scheme provides a far more diverse pool of talent to employers than they can achieve through ad hoc placements granted to friends and family of staff.

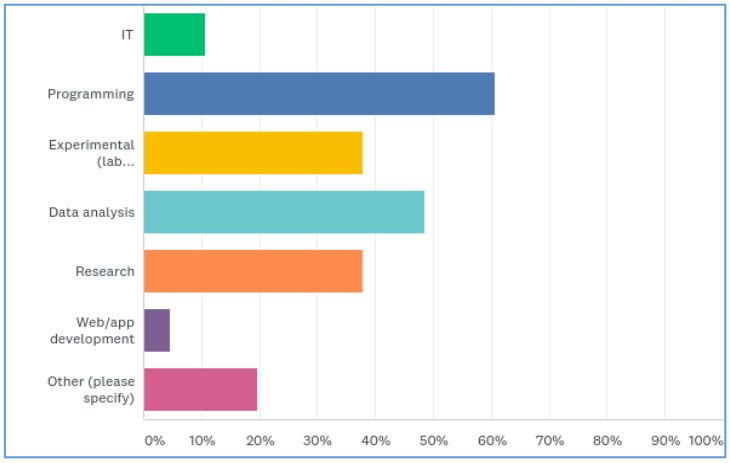

Figure 2. General nature of SEPnet 2019 summer placements (as categorised by employers). Source: SEPnet records 2019/VB

Encouragingly, SEPnet students returning from placements report positive developments in the areas of skills deficits reported in the HEA physics-specific study (Figure 3), while more significantly, employers hosting SEPnet summer placement students likewise report the majority of their students as possessing strengths in these areas, and moreover rated the students more highly than the students self-reported (Figure 4, cf. Figure 1).

Students rated improvement highest for:	**%**
Self-management	74
Problem-solving	69
Communication	69
Teamwork	44
Resilience	54

Figure 3. SEPnet students returning from summer placements most commonly identify that they have developed/improved their skills in these areas (self-reporting percentage given). Source: SEPnet records 2019/VB 10.12.19

Students rated highest for:	**%**
Problem-solving	83
Communication	82
Self-management	80
Teamwork	70
Resilience	75

Figure 4. Employers report the majority of their SEPnet summer placement students as possessing strengths in these areas (employer reporting percentage given). Source: SEPnet records 2019/VB 10.12.19

If the skills deficit reported by employers, and the development deficit reported by new graduates, may be identified with the "skills gap", then the overlap with the **self-reported and employer-reported competencies of SEPnet placements students suggests that the SEPnet summer placement scheme is effective in addressing the skills gap *prior to graduation*.** Summer placements offer an effective and low-risk way for students to gain industry-relevant skills in a short space of time.

[29] 2019: 74 placements were undertaken, from 291 student registrations. The median number of applications per placement was ~13. (Students could apply for more than one placement; most successful students applied for three to six.) Source: SEPnet records (VB, 10.12.19)

Ideally, we would see all students gain some form of work experience, as envisaged by the Wakeham report. For some students, a summer placement may not be an option due to caring commitments or other barriers, so work experience and other responsibilities need also to be recognised as developing relevant transferable skills.

Currently around 25% of applicants gain a SEPnet summer placement (2018 and 2019). Clearly, three times as many students are ready, willing and able to undertake summer placements, if only more were available. We need to enlist a larger number of employers to meet this demand, and to span a range of sectors and company sizes to reflect the wide range of industry needs. **Currently the scheme is limited by the finite number of employers providing summer placements**, not by any unwillingness on the part of students to gain industry-relevant experience.

Sourcing additional placements is a high priority, but as central careers and employability services become stretched, a concerted effort by physics academics is needed to highlight the value of placements to students, to encourage students to source their own, and to share employer contacts with employer engagement teams. There is a large untapped pool of employers whom we are not yet reaching. There is a perception that the skills gap may be more acute away from major cities. Regional SMEs in particular may struggle even more to attract suitably skilled graduates; the Prospects study recognised that most businesses are SMEs but most graduates work for large business, and that SMEs experience more and wider shortages of graduates. There is hope in the finding that graduates tend not to be as mobile as many people assume: SEPnet's recent Employability Survey[30] showed that proximity to home or university is an important factor for 44% of physics students considering a placement, echoing the 2015/16 DLHE data findings that 45% of graduates studied and sought work in their home region, and that a further 24% returned to their home region for work after graduation[31]. In summary, 69% of students seek work in their home regions, so local placements could help to address regional skills needs.

In a recent SEPnet Employability Survey[32], 27% of physics students appeared to be oblivious to the embedding of employability skills in their courses. Clearly, more needs to be done to raise their awareness of the skills they are developing. Part of the problem is that physics students often don't have clear career pathways; they are told they can do anything, but having chosen physics more because they love it than because of the career options it offers, they struggle to focus on what skills they need, or on developing or even recognising their transferable skills. Many harbour a desire to pursue research while knowing little about the career and lifestyle trade-offs involved.

Reflections on 6-12 month undergraduate industrial placements

An IOP response to the 2016 Wakeham Report indicates[33] that 67% of physics departments offer 6-12 month placements. They are valued by students, employers and universities[34], but the take-up is generally low, with the notable exception of Surrey's physics department where around 40% of students undertake a Professional Training Year. SEPnet's recent employability survey[35] showed that the main reason students cite for not taking full-year placements is a desire not to interrupt their studies. Although anecdotal evidence suggests students' reluctance to undertake full-year placements may be linked to student debt, one SEPnet university saw a more than five-fold *increase* in the number of physics students taking full-year placements in the first two cohorts paying £9k fees. Whatever the cause of that *transient* increase, the students' stated *ongoing* desire to avoid interrupting their degrees underscores a major advantage of SEPnet's *summer*-placement model, since this provides paid, industry-relevant experience without extending the degree duration.

The PhD dimension

SEPnet's employer network has recognised the additional skills that come with physics PhD graduates, citing relevant expertise, maths skills, problem solving abilities, the ability to apply theories to real-world problems,

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[30] SEPnet Employability Survey feedback. VB 20.03.20

[31] There's no place like home. A. Hirst & V. Benson. Physics World 10 Oct 2019. https://physicsworld.com/a/theres-no-place-like-home/

[32] SEPnet Employability Survey Feedback. VB 10.03.20

[33] §5.87

[34] See http://www.sepnet.ac.uk/sepnet-graduate-network/case-studies/ for 30 case studies highlighting the benefits for PhD students and employers

[35] SEPnet Employability Survey feedback. VB 20.03.20

flexibility, an enquiring mind, persistence and enthusiasm. Most supervisors would recognise these as *core* characteristics of successful PhD students, whereas the skills gaps associated with first-degree graduates mostly concern skills developed *alongside* the core of a taught physics degree, with the one obvious exception of programming. With graduates of first degrees accounting for the majority of physics graduates and dominating employers' perceptions, it would appear that **the skills gap is predominantly associated with graduates of first degrees rather than with PhD-level graduates**.

Of 106 SEPnet PhD graduates from 2018-19, 69% went straight into non-academic jobs, similar to the proportion (58%) of European Natural Sciences PhD graduates[36]. The fact that SEPnet PhD graduates find employment across such diverse sectors (Figure 5) may suggest they are well equipped to contribute to non-academic organisations. SEPnet supports postgraduate researchers (PGRs) to develop industry-relevant skills by offering short (~ 3-month) PhD placements, taken during or immediately after the completion of the PhD. Such placements also raise students' awareness of how their skills can be applied in industry. On average ~8% of SEPnet PGRs do a placement sometime during their PhD; more needs to be done within universities and by the research councils to encourage PGRs to undertake industry placements.

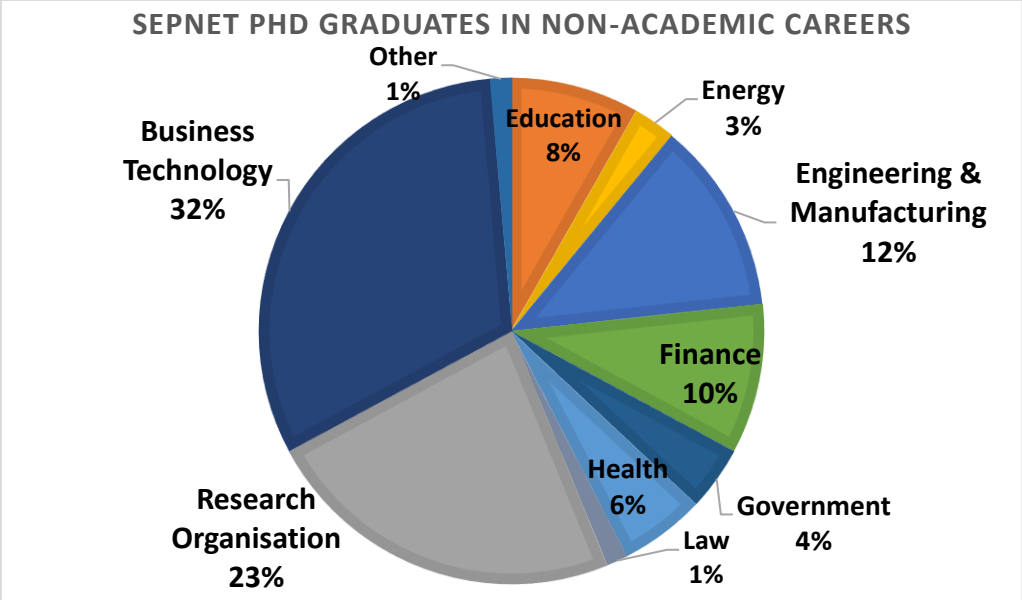

Figure 5. Destinations of 73 SEPnet PhD graduates (69% of cohort) from 2018-19 who went into first jobs outside academia. Source: SEPnet records/VB 19.2.20

The absence of a degree apprenticeship in physics

Degree apprenticeships are designed to meet the needs of specific occupations[37], but SEPnet-led discussions between physics industry leaders and academics in 2017[38] concluded that a degree apprenticeship in physics was not feasible since there is no generic physics occupation (the closest is NPL's metrology degree apprenticeship), as the wide range of work destinations for physics students attests. Employers have also expressed concern about the risks of 'dumbing down' the physics degree through an apprenticeship model; they value students' knowledge of core physics principles which distinguishes them from other STEM graduates. There is no sign that degree apprenticeships will solve the physics skills gap.

[36] Ålund, M., Emery, N., Jarrett, B.J.M. *et al.* "Academic ecosystems must evolve to support a sustainable postdoc workforce". *Nat Ecol Evol* (2020). https://doi.org/10.1038/s41559-020-1178-6

[37] Apprenticeship standards must be developed by employer-led groups known as trailblazers, not by universities, separating the specification of what a degree apprentice must be capable of doing from the institutions involved in teaching them. https://www.gov.uk/guidance/search-for-apprenticeship-standards

[38] (i) SEPnet Employer Engagement Panel 6/7/17;
(ii) http://www.sepnet.ac.uk/sepnet-university-hertfordshire-degree-apprenticeship-consultation/

Summary and recommendations

With technological change and the demand for new graduate skills accelerating, the physics skills gap will be a continually evolving feature of the physics graduate workplace. **Universities and business need to work together, in ways that have been shown to be effective, to reduce the impact of the skills gap** on physicists' futures and on industry. **There is an onus on academics and the IOP** to ensure that physics departments increasingly embed both specialist and transferable skills that graduates and employers have identified, that they increase students' awareness of these skills and their career options, and that sector requirements are updated continually. **There is an onus on employers and industry** to provide the structured placement opportunities wherein students can develop the industry-relevant skills that employers expect graduates to possess. Coupled with the need for a greater *number* of placement opportunities to satisfy the high number of physics students pursuing industry-relevant work experience, **there is a need for more *geographically-diverse* and *sector-diverse* placements, for example provided by SMEs**. SMEs are an important contributor to the UK's economic powerhouse, but historically they have been less likely to offer paid placements. The SEPnet 8-week summer placement scheme involves much smaller financial outlays and time commitments than the traditional full-year placement model, so is well suited to industrial newcomers as well as to students who do not wish to prolong their degrees. Physics students cannot graduate with the full suite of industry-ready skills without the full suite of UK industry providing industry-relevant workplace experiences. **There is also a role for supervisors, research tutors, heads of department, research councils and other funders of research** to encourage PhD students to identify and take up placement opportunities to develop industry-relevant knowledge and skills during their studies.