Digital and Professional Skills for Industry

Understanding Employers and Graduates Experiences

DiRAC

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About the SSI

The Software Sustainability Institute (SSI) was the first organisation in the world dedicated to improving software in research. It was founded in 2010 on the premise that helping individuals and institutions to understand the vital role that software plays in research would accelerate progress in every field of scientific and academic endeavour. The SSI has set itself the ambitious goal of transforming academic culture by establishing the principle that reliable, reproducible, and reusable software is necessary across all research disciplines. Recently, the SSI has moved into policy research, focusing on skills and careers in academia and industry.

About DiRAC

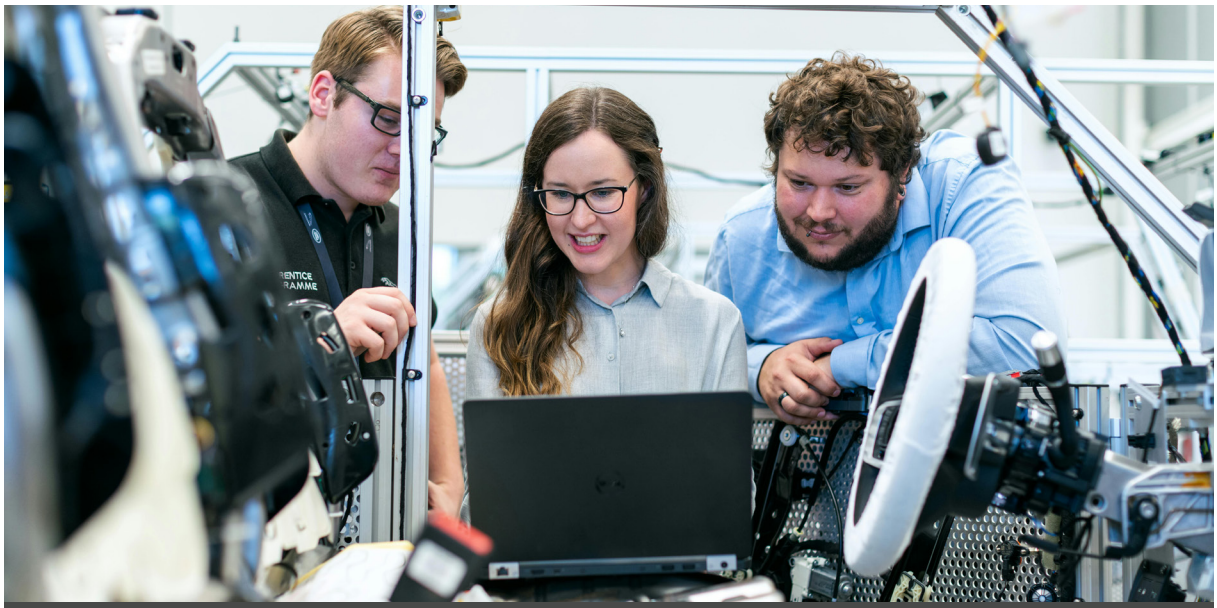
Established in 2009, DiRAC provides high performance computing (HPC) services to the UK's Scientific Research Communities in theoretical cosmology, nuclear physics, astrophysics, particle physics, and solar and planetary science. DiRAC is funded by the Science and Technology Facilities Council (STFC), part of UK Research and Innovation (UKRI). In addition to their HPC services, DiRAC offers a comprehensive training programme, including foundation and more advanced HPC training, artificial intelligence/machine learning (AI/ML) training, vendor sponsored events looking at specific technologies, and Innovation Placements which gives our users opportunity to engage in industry collaborations.

Executive Summary

The major challenges faced by the UK, from increasing productivity to decarbonising the economy, depend on access to a highly skilled workforce. Digital technologies are key to solving many of these challenges, but the skills needed to introduce these technologies are limited and their introduction, especially in the case of AI, presents both opportunities and risks. International competition and the incredible pace of change of digital technologies further exacerbate shortages. Within this complex and changeable environment, it is understandable that graduate skills are sometimes out of step with the needs of industry.

This report provides analysis into skills gaps for UK graduates as they transition into software engineering and data science roles within industry and the public sector. Drawing on qualitative data from 26 interviews with employers, recent graduates and industry stakeholders, we analysed perceptions of the skills graduates bring as well as skill gaps, and the causes of these gaps. Our findings did not reveal substantial technical skills gaps. Employers felt that widely applicable technical skills in coding and good foundations in maths and science were well represented in recruits. However, those technical skills developed through practical experience were less present. Employers were more concerned about the gaps they perceived in recruits' professional skills: communication, teamwork, project management and commercial awareness were seen to be lacking. While large employers were able to address skill gaps, small and medium-sized enterprises (SMEs) had more constrained resources, meaning they struggled to provide training, making workforce readiness more challenging in this vital part of the sector.

Several recommendations are made to improve graduate readiness. There should be more collaboration between employers and HEIs to integrate practical teaching and industry-like work into modules to ensure that students gain practical, real-world experience before entering the workforce. Internship programmes should be expanded with HEIs developing stronger partnerships with local employers to provide opportunities for all students. SMEs should consider investing in their own training or work with external trainers to provide this. Increasing industry involvement in curricula development, dealing with technical skill gaps that exist by increasing the teaching of applied digital skills needed in industry, and supporting professional skills development, especially related to working within teams, the UK can cultivate a workforce equipped with the skills necessary to sustain digital transformation and competitiveness in the UK economy.



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Key Findings

- **Technical Skill Gaps:** Graduates typically possessed fundamental technical skills required, in particular the ability to learn software languages. However, they lacked practical experience in areas like software testing, deployment, and version control.
- **Professional Skill Gaps:** Higher education was effective at training students to work and learn independently. However, skills such as communication, teamwork, and commercial awareness were often underdeveloped.
- **Internships and Practical Experience:** Internships and hands-on experience were critical in bridging skill gaps, particularly in professional competencies. Graduates with industry placements are sought after and adapt more effectively to workplace demands,
- **Resource limitations in SMEs:** Small to medium enterprises (SMEs) struggle with the resources to train graduates effectively, as many lack formal graduate schemes and depend on in-house skill development, creating challenges in workforce readiness.

Recommendations

1. Employers and HEIs develop opportunities for collaboration to design programmes and modules that embed practical teaching and industry-

based case studies. This collaboration could be via forums, networks and workshops that bring together programme leads and employers' representatives involved in recruitment and training. Equally, collaboration could involve more targeted partnership between an employer organisation and a HEI who they regularly recruit from. The goal of these relationships and dialogues would be to explore ways to embed industry practices though practical workshops and project-based learning.

2. Employers and HEIs collaborate to provide more, and more inclusive, opportunities for industry based placements and internships, so that larger numbers of students on a programme could take part in work-based training. As above, this would mean universities and employers forming closer partnerships to ensure internships are designed to fit with university schedules and supported by university structures.

3. Where organisations do not have the capacity to offer internships, they could consider investing in external training opportunities that focus on providing industry-relevant teaching of professional skills that could be useful to both HEIs and employers.

Introduction

As technology becomes integral to all sectors of the economy, employers increasingly require skilled workers with technical capabilities in areas like programming, data analytics and AI. Recent policy and industry discussions in the UK have underscored the importance of digital skills for sustaining economic growth and global competitiveness. UK Government initiatives, such as the Digital Strategy 2017 and the establishment of Skills England in 2024, reflect an effort to enhance workforce readiness for a digital economy. However, policymakers, industry bodies and employers themselves often paint a dire picture of the digital capabilities of the UK's workforce with a widespread shortage of digital skills described as a major economic concern (CBI 2019). This report focuses specifically on UK graduates at all levels including research software engineers, as they transition into software engineering and data science roles and the employers in industry and the public sector who recruit them.

Drawing on data from a qualitative study funded by the Software Sustainability Institute (SSI) and DiRAC, we explored the skill gaps as experienced by both employers in different sectors and graduates in their first industry role in those sectors. The findings highlighted how the perceived skill gaps were highly dependent on the employers' expectations about their technical and professional needs, their capacity for training and university curricula. The research identified

a distinction between the ‘technical’ skills employers were looking for such as coding languages, and the ‘professional’ skills they were hoping for including teamwork and commercial awareness. A central finding was that the professional skills gap was of far more of a concern for employers than any deficits in technical skills. Linked to this was the importance of internships and industry placements as mechanisms for bridging skills gaps and facilitating the transition to industry. There were also important differences in expectations between SMEs, with limited resources for training, and Global technology companies, with well-resourced graduate training programmes.

The findings have implications for policy and practice. First, they indicate the need for closer collaboration between employers and HEIs in the design of programmes and modules to imbed more practical teaching and industry practices though practical workshops and project-based learning. Second, employers and HEIs should collaborate to provide more opportunities for industry based placements and internships so that larger numbers of students on a programme could take part in work-based training. Finally, findings indicate the value in developing a targeted training package to equip UK graduates with the critical skills required in technology-focused roles. Through these insights and initiatives, the report contributes to ongoing efforts to build a resilient, skilled workforce capable of driving innovation and competitiveness in the UK’s digital economy.

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Background

Digital skills encompass a broad range of abilities necessary to use and leverage digital technologies effectively in various contexts. These skills range from basic digital literacy, such as using computers and navigating the internet, to more advanced competencies like software engineering, programming, data analysis, and cybersecurity (van Laar et al., 2017). In the UK and globally, workers with digital skills have become increasingly central to industry, driven by the rapid pace of technological advancement and digital transformation across sectors (World Economic Forum, 2023). As businesses increasingly rely on digital technologies for operations, communication, and service delivery, a workforce equipped with relevant digital skills is essential for economic resilience and growth (Nania et al., 2019). They are seen as crucial for driving innovation, improving productivity and maintaining competitiveness in a globalised, knowledge-based economy (OECD, 2023). Consequently, the development and availability of workers with these skills have become a key focus for policymakers, educators, and industry leaders alike (Open UK, 2023; DCMS, 2017).

The increasingly urgent need for workers with digital skills over recent decades has been accompanied by policy and industry narratives that often paint a dire picture of the UK's digital skills landscape. Businesses and policymakers frequently cite a widespread shortage of digital skills as a major economic concern. Organisations like the Confederation of British Industry (CBI) have consistently reported that businesses struggle to fill tech roles, with their 2019 survey indicating that 67% of firms were experiencing digital skills shortages (CBI, 2019). Tech companies echoed these concerns, with research by Microsoft, conducted with Goldsmiths University of London, suggesting that the UK faced a significant shortfall in advanced digital skills (Brauer, Barth, and Ahsan, 2020). A recent industry survey for analytics company Reveal reported that tech firms faced a sustained shortage of developers, and this workforce were missing technical skills, and project management and business skills (MacRae, 2023). However others have cautioned that the skills gap rhetoric serves the interests of tech companies and educational institutions rather than reflecting real issues in the workforce (Livingstone and Blum-Ross 2020).

The UK government has also sought to address the digital skills issue. Initiatives like the Digital Strategy 2017 highlighted the need to address the skills gap to maintain economic competitiveness (DCMS, 2017). More recently, the All Party Parliamentary Group on digital skills (APPG on Digital Skills, 2023) and the Digital Skills Council (which aims at bringing together business and government to support digital skills) have continued to emphasise the need for better digital skills in the workforce. These narratives have to a certain extent led to increased intervention and investment in digital education and training programs, including

government-funded basic digital literacy training and coding bootcamps to support the general workforce (Gov.UK, 2024). The government has also funded master's degree conversion courses in Artificial Intelligence (AI) and data science, as well PhDs in AI (DCMS, 2017). UK Research and Innovation (UKRI), through the EPSRC and their centres for doctoral training, provides funding to Higher Education Institutions (HEIs) to deliver training to research students, with each HEI deciding how this is used depending on the needs of researchers (UKRI, 2024). The Labour government elected in 2024 quickly established Skills England to support skills training. Skills England states that it seeks to collaborate with businesses, training organisations and unions to develop a highly skilled workforce capable of fulfilling the demands of the Industrial Strategy and achieving Net Zero goals (Department for Education, 2024). However, specific interventions around digital skills have not yet been detailed.

Little of the policy literature provides detail on the specific dimensions of the skills gaps. Academic debates reveal a more complex picture. They explore what skills employers are looking for, what are their expectations, and how these shape what they consider graduates to be lacking. Research distinguishes between technical software skills and professional or 'soft' skills – such as communication, teamwork and problem solving (Groeneveld, Vennekens, and Aerts, 2022). Findings suggested higher education delivered well on technical skills, but less so the professional skills which were missed in the focus on lecture-based learning (Yépez et al., 2023). Hands-on project work and industry placements were shown to complement higher education by fostering these essential skills (Richardson and Delaney, 2009; Jackson and Bridgstick, 2021), but not all students were able to access these opportunities.

A second question relates to the level at which the gaps exist. Is the issue with undergraduates in their first job post degree (Garousi et al., 2019) or with those who are at postdoctoral level (Voitenko, Gadasina and Sørensen, 2018) when they enter industry? In addition, there are also research software engineers (RSEs) who have completed a postdoctoral period of employment in UK higher education institutions building software to support research (Goth et al., 2023). Employers recruit at different levels, sometimes all three, and are likely to have different expectations about the skills these groups will bring (Adams, 2023).

A third dimension of the skills gap is that employers operating in different sectors and delivering different products and services may require different skills and identify different gaps. The UK hosts an array of employers delivering web services, business support, finance, and grocery retailers (Glassdoor.co.uk, 2024) each with slightly different needs in relation to the software and digital skills they are looking for. For instance, financial services rely on engineers proficient in secure cloud architectures to safeguard sensitive data and comply with data privacy laws, while green tech jobs need a strong grasp of data analysis and automation (Engineering

UK, 2023). Is it possible that the skills gap exists only for employers in certain sectors?

Finally, an organisation's size and resources are also likely to affect how and who they recruit. Large and prestigious firms that can offer competitive salaries, benefits, and career progression opportunities, will be able to attract the most talented graduates (Deloitte, 2022), and that might mean those with the most well developed skill sets. Conversely, SMEs and lesser-known companies may struggle to find suitably qualified people to fill roles, and limited resources to provide their own training in order to address gaps in their recruitment (BCS, 2024). Public sector organisations, especially those with a specific technical remit, may have very particular technical requirements but might struggle to match commercial sector salaries (Cribb and O'Brien, 2024).

This study aimed to explore how employers in different sectors, using software in delivering products and services, and who regularly recruit UK graduates at various levels (undergraduate, doctoral and RSE), experience skill gaps. It aimed to triangulate that by exploring how graduates themselves experience the transition to industry and their own perception of skills gaps. Findings were designed to inform policy and practice and to shape a targeted training package offered by the SSI and DiRAC focused on students in UK HE and those in their first job in industry.

The study's research questions were:

1. What are employers' experiences of graduate skill gaps?
2. How does this experience vary by the size and sector of the employer?
3. What are the characteristics of those skill gaps? i.e., technical or 'professional' skills,
4. What are graduates at different levels (undergraduate, doctoral and RSE) experiences of the transition to industry? How do they understand the skills they bring and those they need to acquire?
5. What are the possible causes of skill gaps?
6. What training could be done to address particular skill gaps?

Methodology

Our research was designed to capture both employer and new recruits' experience of the transition from HE to industry and the nature of any potential skill gaps. It consisted of a small 5 month qualitative study over spring and

summer of 2024, involving 26 online interviews. Drawing primarily on SSI and DiRAC networks we sought to interview employer representatives in a variety of organisations who recruited from the UK's skilled graduate pool including large global technology companies, national and public sector infrastructure organisations, and small and medium size companies and startups with a substantial reliance on digital technologies. A second group of interviewees were those who had recently made the transition to a software role in industry, including those with masters degrees and doctorates and those who had worked as research software engineers in higher education institutions. These two broad groups would allow us to address the research questions and explore the way companies and graduates experienced and understood potential skill gaps, the nature (technical or professional), scope and causes of those gaps.

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Ethics

Approval for the study was sought from the University of Southampton's ethics committee. Prior to interview, potential participants were provided with an information sheet and consent form that provided details about the aims of the research, the interview process (such as audio recording and transcription), confidentiality and anonymisation processes and data storage and archiving. Anonymity was emphasised as we wanted participants to feel they could speak freely about their experiences despite the sensitivity of skills and capability issues and organisational reputation. Participants signed an email consent form. Interviews were transcribed, and transcripts pseudonymised and retained for archiving in a University of Southampton data repository. Names of organisations and individuals have been replaced with anonymous identifiers in this report.

Recruitment & Sample

Participant recruitment involved several strategies. The network of SSI and DiRAC industry contacts enabled us to recruit large global technology companies but more targeted recruitment was needed for Small and Medium Enterprises (SMEs) and public sector employers. We struggled to recruit SMEs and start ups despite efforts to include them. The graduate participants – those who have moved from academia to industry in the past 3 years – were recruited partly through the employers we interviewed, but also through UKRI doctoral training partnership networks.

The sample of 26 participants (see Table 1) was constituted by three subgroups. Two key informants were interviewed early in the data collection phase. They were colleagues with long careers developing software in industry and academia, and could provide a broader picture of the skills issues as well as their experience of making transitions between UK HE and industry. These interviews acted as pilot interviews and helped us refine the interview questions.

Seventeen interviews were conducted with representatives of 11 commercial and public sector employers who were operating in technology-focused industries and regularly recruited and employed UK graduates into software engineering roles. Seven were global technology companies (multinationals with a combined 428,000 employees and operations across the globe), two were UK Small and Medium Size Enterprises, and two were UK large government organisations. The technology companies were all involved in developing software for personal and business use, including an AI company, engineering applications company, and an online retail platform. The SMEs were using software in telecommunications, technology systems, or machine learning tools. The two government organisations developed and utilised software to support their broader operations, and conducted data analysis on large datasets. The participants we interviewed from these companies were mostly in senior management, training or line manager roles, and were often experienced software engineers. They were all involved in either recruiting new graduates and/or working with them in technical teams.

Seven interviews were conducted with graduates in their first software role in industry, who had made a transition from academia in the previous 3 years. Five had a bachelor's or master's degree (with one having started a PhD). One of these had a non-technical degree, while the others had engineering or computer science degrees. The remaining two graduates had STEM PhDs and one had been an RSE for five years before taking an RSE role in industry. Four graduates worked in multinational corporations (MNCs), and three worked in SMEs.

Table 1: Participant information

Organisation identifier	Size	Type of organisation	Participants and their role
MNC1	Large 10-50k	Software	E9: Customer technical support. E10: Technical advisor supporting sales.
MNC2	Large >100k	Software	E4: Customer technical support.
MNC3	Large <10k	Software	E8: Customer technical support. E11: Director of engineering. E14: Training manager.
MNC4	Large 10-50k	Software	E2: Work coach E12: Early career talent manager.
MNC5	Large >100k	Software	E13: Research support.
MNC6	Large <10k	ML/AI	E5: Software engineer.
MNC7	Large 50-100k	Software	E17: Software engineer, team leader.
SME1	Medium 50-250	Telecoms - Hardware / software	E1: Chief technology officer. E3: Head of Software.
SME2	Medium 50-250	ML/AI	Graduate (see below)
SME3	Medium 50-250	Embedded software	E15: Electronics engineer, team leader.
SME4	Medium 250-300	ML/AI	Graduate (see below)
Gov1	Large 10-50k	Local government infrastructure	E6: Team leader/Data scientist. E7: Data scientist.
Gov2	Large <10k	Government agency	E16: Training manager.
Graduates	G1: Software engineer in SME. MSc in Electrical Engineering.		
	G2: Research Software Engineer in MNC. MSc in High Performance Computing.		
	G3: Sales and customer service in MNC. BSc in Business Studies.		
	G4: Software engineer in MNC. MSc in Computer Science.		
	G5: Research data scientist in SME. PhD in Particle Physics.		
	G6: Software engineer in Gov agency. MSc in Computer Science.		
	G7: Data scientist in SME. PhD in Physics.		
Stakeholders	S1: Research software engineer. Commercial sector and consultancy.		
	S2: Research software engineer HE. 20 years commercial software engineer		

The Interviews

The interviews were designed to last between 45 minutes and 1 hour, and conducted online following a semi-structured topic guide. We asked employers about their own careers and route into industry, and career, their current role, organisational practice around recruitment and experience of training and working with new starts. We explored in detail their understanding of what new recruits bring to the organisation and the technical and professional skills they lack; as well as perceptions of the reasons for any skill gap. For the graduate interviews we explored their education history and path into work, their motivations for study and their move from academia to industry, and the challenges they faced when starting work and their own perspective on what they brought to the organisation and the technical and professional skills they might lack. We asked both groups for recommendations for training that the SSI/DiRAC could offer to address skill gaps they had identified.

Data Analysis

After transcription of the audio recording, interviews were coded in Atlas.ti qualitative data analysis (QDA) software. We coded to broad thematic and descriptive codes reflecting the literature and our research questions. These included career, recruitment, training and support, technical skills, professional skills, skill gaps and their causes, and recommendations and policy. Later more fine-grained coding captured different categories of skills that were discussed including technical skills: testing, version control, build systems/processes, cleaning data, performance optimisation, containerisation etc. Under professional skills we identified a large range including communication, asking for help, team work, commercial awareness, timekeeping etc. These codes enabled us to analyse and understand employers' recruitment processes, their expectations of skills recruits would bring, those they thought were missing and why, and what might be done to address them, for example in the form of training.

Findings

The seventeen employers interviewed from a range of technology-focused industries were all regular recruiters of UK graduates into their software engineering teams and roles. These included technology focused senior management roles such as Chief Technology Officer, Director of engineering, training and recruitment (e.g., early career talent manager), or line management

(e.g., software engineer team leader, training manager). They were all involved in recruiting new graduates, working with them in technical teams, and training and supporting new recruits. They provided a range of experiences of graduate skills and recruitment and different perspectives on where they felt the gaps were and what caused them.

The seven graduates we interviewed had taken a range of different pathways and shared valuable insights on transitioning from higher education (in STEM or software engineering) to software focused roles in industry. Five entered industry with a bachelor's or master's degree, two had PhDs, and one of those had been an RSE for five years. Five had also completed internships during their degrees, with three (G3, G4, G6) continuing in the same organisation post-graduation. Two others completed placements during undergraduate (G1) or PhD (G5) studies.

Recruitment & Onboarding

A variety of recruitment strategies were discussed by the employers, shaped by the size of the company and its resources and needs. For example, one global technology company ran a graduate recruitment scheme over six months involving online tests, assessment days, and a series of interviews (MNC4). They offered competitive salaries and recruited at all levels to this programme including high numbers of PhD recruits (50%). The SMEs did not have regular formalised graduate recruitment programmes in the same way. SME2 had recruited three or four data scientists a month on a rolling recruitment advertisement during a period of growth but this tailed off as demand slowed. Employers such as SME1, MNC1 and MNC6 recruited PhD graduates and RSEs through specific job adverts targeted at those with the very specific domain knowledge they required, for example in telecommunications or machine learning. One of the SMEs had links to a UK university and sought out graduates recruits through their contacts. Advertised roles and graduate recruitment programmes received different levels of response depending on organisations' size and profile. MNC4 explained they received around 3000 applicants per recruitment round, whilst SME3 described how they struggled to get adequate applications for their graduate programme. They cited a combination of factors for this including their relatively low profile, a late recruitment round, and a company demand for on-site working in contrast to many of their competitors. The competitiveness of the package being offered was critical to organisations ability to select recruits.

In addition to the recruitment programmes, the larger employers in the commercial and public sector ran a regular internship programme which served as a recruitment mechanism. These were usually offered as a sandwich year. For example, MNC2 and MNC7's programmes ran for 13 months between students'

second and third years at university. Many recruited their interns through links with a specific university department or programme. Others offered shorter programmes in university summer break periods. Gov1 provided 6 month internships for PhD students. The intern recruitment process could involve several rounds of tests and interviews. For example, MNC2 ran phone interviews followed by psychometric and HR reviews, then an assessment day. These companies went on to recruit a proportion of their graduate trainees from their placement programmes. E11, a Director of Engineering at MNC3, thought internships were a good way to reduce risk when hiring as it enabled employers to see how students fitted with the company. Some organisations also offered successful placement students a salary while they completed their final year of study, having recruited them at the end of their internship (Gov2, MNC2).

Employers also differed in their approaches to onboarding and training of graduate recruits. Larger organisations ran extensive programmes, often spanning 18-24 months, designed for ex-interns and external recruits alike. These involved a combination of face-to-face and online training packages, work shadowing in different teams, mentoring, and regular reviews of progress. For example, E5, a software engineer at MNC6 had a set of exercises that were designed to guide their new graduate recruits through their processes with various tasks that facilitated them interacting with 'all the bits of the system'. This allowed recruits time to develop their software skills before starting to contribute to a commercial team. Organisations were also strategic about which elements of training they provided in their onboarding process. One government employer felt they were able to recruit graduates who already had relevant industry experience in other companies and had developed the required professional skills such as team working and communication. On this basis they did not provide this training as part of their process for new recruits (Gov1). From the perspective of the graduates we interviewed who were working in large organisations, their experiences of onboarding and training included work shadowing and tailored training programmes (G3), as well as mentoring (G2).

The SME employers described their graduate onboarding process as happening 'on the job', although they stressed this was in an organisational culture of mutual support and continuous learning. Their graduates were more likely to develop their technical and professional skills in the direct delivery of products and services to clients. SME4's onboarding scheme involved rotating recruits around different teams. SME3 provided extensive training to their small graduate intake, despite their limited resources, because they struggled to attract graduates with the right skills and felt this training was crucial. Graduates in SMEs reported online training and shadowing and G7 described informal support through colleagues' guidance: 'If you ask somebody for help, everybody will happily schedule a call with you… because in the long run, that's beneficial for everyone'. Their stories

were not all positive. Another reported that their SME employer had made the learning and development team redundant because they felt they could ‘hire good people’, and not need to train them (G5).

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Understanding Technical & Professional

The interviews explored the various skills that employers described as being crucial to their work and what they wanted to see in graduate recruits. Similarly, we asked graduates what skills they thought their employers were looking for, what they brought specifically, and what they felt they needed to learn. We explored both technical skills – the specialist expertise needed for software engineering roles; and professional skills, or soft skills, such as working in a team or communication with different stakeholders. Employers saw both as essential in a professional technical workplace but it was often the professional skills that occupied more of the interviews and a very wide range of skills were discussed in this context.

Technical Skills

The technical skills fell into two overlapping groups, those widely expected of new recruits in various industry settings, primarily software development, and those that were more organisation-specific technical skills required for specialised roles. The widely-applicable software development competencies included both knowledge of software languages and coding but also specific aspects of

software development such as testing, deployment, version control, performance optimisation, containerisation, build systems, and data cleaning. In addition to the more foundational software skills, several employers mentioned valuing recruits who were interested in learning new languages, and those who keep up with recent technical developments. This interest in and capacity for learning software languages was seen by employers as a key aspect for understanding whether recruits would be able to contribute fresh ideas and perspectives. Employers who recruited PhD and RSE graduates with specialist skills noted that they expected a foundational understanding of science and engineering practice in these recruits: 'we want a strong STEM background; that's the one thing we're not going to be able to teach, basic statistics and maths, algebra. All this stuff needs to come from before' (Gov1).

Employers also discussed the need for various domain- or organisation-specific technical skills relevant to their particular operations. Different organisations sought knowledge of specific coding languages. For example, MNC7 valued knowledge of Go while SME3 needed people with C++ – both compiled languages. They also looked for familiarity with, or the ability to quickly adapt to, industry-specific tools, frameworks, and standards, whether that was knowledge of industry standards (SME1), ways of planning code such as test-driven design (Gov2) or quickly being comfortable with the systems that an organisation runs (MNC3, MNC6). The SMEs were particularly focused on finding recruits who had domain specific knowledge of the particular field they were delivering. For instance, SME1 required PhD graduates with domain knowledge of wireless communication. We found that organisations were more likely to expect domain knowledge from PhD graduates and RSEs than undergraduates. They understood that domain- and organisation-specific skills would usually require on-the-job training.

Professional Skills

The interviews with employers across all types of organisations revealed a strong concern with the professional skills needed to work effectively in industry. These skills spanned a broad range of competencies from teamwork to commercial awareness, and varied by the particular role the graduate was located in. All employers valued graduates who demonstrated an interest in **continued learning**, an ability to quickly pick up new skills – particularly coding languages or specific domain knowledge – through self-teaching and online training. They valued candidates who developed software in their spare time and showed a commitment to developing the skills needed to write high-quality code (Gov1). Several mentioned that in recruitment interviews they focused more on understanding candidates' learning process, motivation, and adaptability to new contexts, than what they already knew; 'these are things that indicate how

easily their hard skills will transfer to the other areas' (MNC3). Adaptability to new contexts and an organisation's specific practices and software choices was a key dimension of the ability to learn new things. The RSE explained how it had been important that they were able to adapt to multiple teams and their different processes: 'You can't be married to any particular system… being able to follow whatever a group's process is, is useful' (G2).

Another key soft skill discussed by all the employers was **team working** and its importance for software engineering which, in an industry context, is almost entirely undertaken in teams. As one employer pointed out about their processes, 'there's no piece of code that is handled by only one person, […] you really need to be able to collaborate and work with others to be effective in this company' (E14, training manager at MNC3). There were a range of dimensions to team work skills discussed as being important for candidates and recruits to understand. These included prioritising the needs of the team over individual goals or interests, cooperating with people from different disciplines, tactfully getting others on board with ideas, being willing to share credit rather than promoting individual success, and being considerate of colleagues' time. On a more pragmatic note, punctuality was also felt to contribute to good teamwork.

Aspects of **project management and lifecycle** were also discussed as important skills in most interviews although the level of responsibility mattered in terms of what was expected. For RSEs and PhD graduates in more senior roles or in small teams delivering projects to clients, it was seen as essential that they could demonstrate an understanding of the overall structure of project delivery and management. For graduates more generally, employers highlighted the importance of knowing how to use software lifecycle management processes such as Waterfall and, more often, Agile: 'Agile is literally how to work in a team, like a multidisciplinary team' (E16, a training manager at Gov2). Linked to project management, employers and graduates emphasised time management as a crucial skill that facilitated the necessary prioritising of work tasks, and an understanding of what level of quality is 'good enough' to meet business needs.

Good **communication skills** were identified by employers as crucial for success in industry and essential to good teamwork. Participants discussed the need for workers to be able to effectively communicate with different audiences and to translate technical knowledge to both customers and non-specialist colleagues and senior managers. As one participant put it, 'We need to be talking the same language' (E7, a data scientist at Gov1). Communicating effectively with clients and customers was a crucial element of many software roles and included particular aspects like needs-finding and negotiation: 'You need to be able to approach the product owners, book that meeting, and start to probe and tease out what it is they need' (E15, a team leader at SME3). Another dimension of communication skills which overlapped with teamwork was the necessity of articulating problems

and challenges and asking for help when needed: 'You've got a problem; just go and ask' (E3, SME1).

For the commercial and public sector organisations alike, **commercial awareness**, an understanding of 'bottom line' and the need for time and resource efficiency and reputation management, was a crucial element that recruits needed to understand. As E3, Head of Software at SME1 explained, new recruits needed to understand that unlike at university they had to deliver something that was good enough to do what was required rather than a comprehensive solution: 'What I want is something that's... the bare minimum function – that will allow me to deploy it as quickly as possible to a customer'. The need to promote the interests of the company was also noted. For example, one employer noted the importance of taking opportunities to sell other products or services (MNC3).

Exploring Skill Gaps

Establishing skill gaps was not straightforward. Expectation of graduate skills by employers was a key aspect of what they understood as a gap and this also differed according to the level at which organisations were hiring. As the previous sections noted, there were a range of domain- or organisation-specific technical skills including programming languages and the organisation's software tools, frameworks, and standards that they did not expect new recruits to possess on entry, with the exception of a small number of PhD students specifically recruited for domain knowledge. Employers noted that specific coding languages were often not known by recruits, either because they were older languages no longer taught at university (MNC3, SME3) or newer ones like Go (MNC7) that had not yet reached higher education. As such these were not specifically viewed as skills gaps because they were anticipated, and organisations aimed to address them through in-house training.

In contrast, employers felt that graduates should and usually did possess the more widely-applicable technical skills. There were many positive accounts of graduates' foundational understanding in science and engineering, developed throughout their degrees. Most employers felt graduates arrived with a good grounding in a number of coding languages and they valued the graduates' capacity to learn new languages rather than depending on their existing language skill set. Even the STEM PhD graduates, hired for their domain knowledge, were considered to be quick to pick up the new coding skills needed for their work. Having said that, several employers grumbled about which programming languages universities prioritised. For example, one employer felt there was too much focus on interpreted languages like Python, and not enough on compiled languages such as C++ (E15, SME3) and another noted the slowness of universities to engage

with new languages such as Go (E17, MNC7). Overall there was some sympathy for the task that universities faced in this area. One participant likened universities attempting to teach industry-required programming languages to a game of 'whack-a-mole,' given the frequent innovations and developments (E2, a Agile work coach at MNC4).

The technical skills that were explicitly raised as skill gaps by employers were more minor elements of a software engineers toolkit often linked to the practical application and use. These included testing, deployment, version control, performance optimisation, containerisation, build systems, and cleaning data. Employers felt that to get to grips with these skills, they were 'something that you have to deliberately practice' (E2, MNC4), which was missing from most of the university experience. E17 (team leader at MNC7) felt that to ensure reliability and quality, testing was an important part of software development projects in an industry context, and was particularly concerned about the lack of understanding of this in their graduate recruits: 'This is where a lot of young people fumble'. They pointed out that whilst testing was probably taught briefly, students had little opportunity to practise it outside the context of a final year project.

An important finding to emerge from this is that there was not a substantial technical skills gap identified by employers recruiting UK graduates. What was more concerning for those employers were the gaps they perceived in recruits' professional skills. Exploring professional skill gaps revealed a further interesting distinction. Graduates' learning skills tended to be discussed in a positive light, while project management, communication, team work, and commercial awareness, were primarily framed negatively, as areas where gaps existed. Employers considered graduates to be good at **learning** new things, linking this ability to the independent learning style fostered in higher education and particularly the acquisition of multiple coding languages. Graduates also recognised this. Recalling the challenges of doing a PhD, one said 'the skills it's given me now, being able to basically start from nothing and pick up a new skill from scratch… I think it's probably my key strength now' (G5). Others highlighted how their university degree helped to develop independent problem solving skills as well as perseverance (G2, G7).

Employers were less positive about other professional skills that they felt graduates often struggled with or lacked when they first arrived in the organisation. **Communication** was a key issue. There were several dimensions to this. Graduate recruits were felt to be poor at discussing their work with non-technical audiences (clients and colleagues). Employers and graduates saw this as an inevitable result of undergraduate and research degrees where most communication was with academics or peers and there was little exposure to non-technical audiences or those in other disciplines. This was also the case for PhD graduates. One employer (E7, data scientist at Gov1) explained: 'When you

come from academia, you're designing things for "up here", when in reality, we probably need to be pitching "[down] here" to just be talking the same language'. Generally, recruits were felt to lack confidence and experience of presenting to groups. Again it was suggested that this was a result of the focus on the book/computer-based assessment and teaching and a lack of opportunity for group and project work at university (S1).

Teamwork and the communications skills this required was identified as a gap by the majority of participants. Employers noted that graduates often struggled to adapt to working as part of a team. E16 (Gov2), a recruiter and trainer of graduates, pointed out that graduates' lack of experience working in multidisciplinary teams meant they were … 'not used to working with that range of people'. They were unfamiliar with a team setting in which they were expected to contribute a small part to a large codebase, rather than seeing entire projects through (G4). This necessitated extensive communication with other colleagues in the team, rather than working alone to solve a problem. One employer also noted that coming from an individualised assessment context in HE, collaboration among students could 'feel like cheating' (E14, training manager at MNC3). Again these issues were no different for research graduates. In fact, E14 suggested PhD graduates struggled to adapt to team working more than undergraduates, possibly due to the length of time they had spent working independently.

One particularly important element of teamwork that was also a **communication** issue was mentioned by several employers; asking for help. Employers noted that recruits who were not able to communicate to their teammates that they needed support, wasted significant time struggling on their own. One participant felt this highlighted the difference in cultures between HE and industry: 'There are no prizes for going off and learning it yourself and taking three times as long. You've got a problem; just go and ask' (E3, Head of Software, SME1).

Project management was identified as a skill gap by several employers who noted that graduates often lacked experience with software lifecycle management processes such as Agile. One employer with insight into higher education pointed out that whilst Agile was taught on computer science degrees, it was rarely done effectively. Agile techniques like daily standups were developed for industry settings, requiring a level of immersion that, it was noted, was difficult to replicate in an academic environment when students only worked on a project once a week. It is 'very difficult to teach that stuff' in a way that mirrors real-world application (E2, work coach, MNC4). A recent PhD graduate described his struggle with the demands of his current job that required planning, prioritising tasks, and creating timelines, a skill set he admitted he had not really needed in his PhD and was still developing (G5).

Finally, a lack of **commercial awareness** was identified by several employers who

felt that their graduate recruits struggled to understand the need to prioritise efficiency, something that does the job at hand without wasting time and resources, over the perfect output. E3 highlighted that his business needed 'the bare minimum function that will allow me to deploy it as quickly as possible to a customer', but students and researchers were used to having more time to develop software and were not used to working with a set of external constraints of the sort that existed in an industry setting. E8, customer support at MNC3, highlighted how graduates could be too focused on their own goals rather than those of the company: 'There's a lack of end-to-end thinking. They want to close the ticket and move on [but] I'll say, "Let's think beyond what's in that ticket... Is there any way that this ticket could have helped... me build relationships with this customer?"' A graduate working in software sales said that she struggled to persuade software engineers that they sometimes needed to step out of their comfort zone and engage in new ways of working, if it brought in new money to the organisation (G3).

The Role of Internships

A central finding of the study has been the importance of internships in bridging the gap between university and industry. Employers saw internships as providing students with the practical opportunities to apply technical skills learned in lectures in industry contexts, and to develop professional skills that HE's structure and teaching activities could not adequately support. Larger organisations were able to provide year long sandwich style internships or placements with well-developed curricula and learning goals. For example, MNC2 assessed communication, organisation, and technical skills, all of which were scored and rated, with training tailored to each intern. Providing an example of their

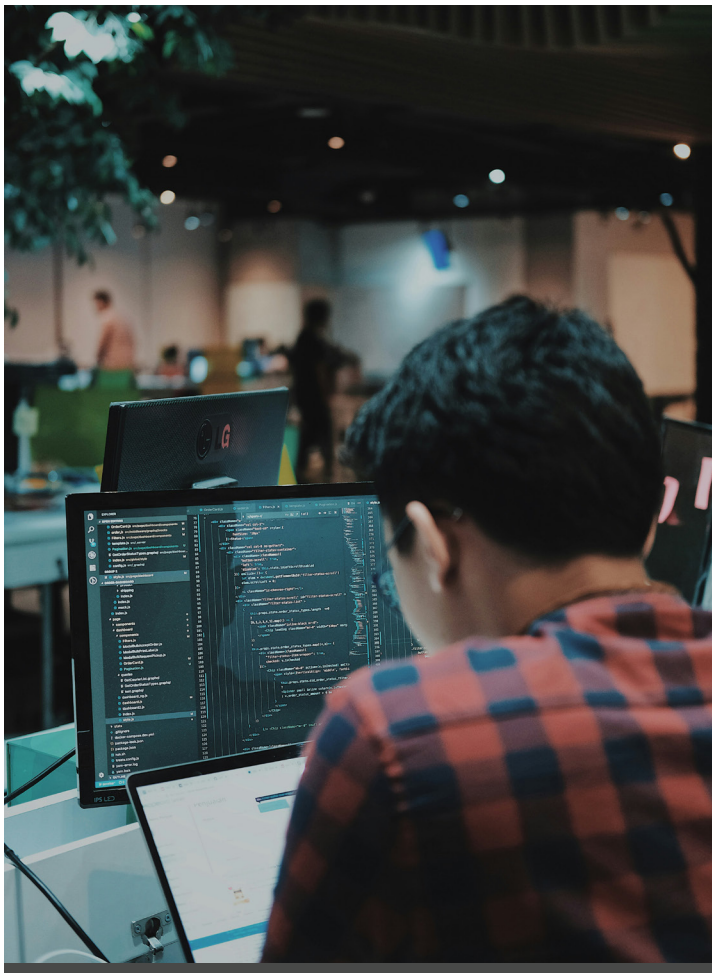

Photo by Arif Riyanto on Unsplash

own well-resourced internship scheme, E14, training manager at MNC3, described a blend of learning and practical experience, and a mix of technical, professional, and leadership skills including career development, and time management. Interns were also given the opportunity to work directly with customers, strengthening their problem-solving, teamwork, and communication skills. G3 said that after work shadowing, she was 'thrown in at the deep end talking to customers, and you just have to work it out as you go along'. Others noted that interns learned about organisational structures and received opportunities for personal and technical growth. E3, Head of Software at SME1, felt that a key benefit of internship was that it exposed students to the commercial realities of industry and helped them develop 'a different perspective'. Graduates echoed these views. G1 described how working in a supportive industry environment boosted his confidence in 'doing those soft [professional skill] things,'. Similarly, G4 felt they gained maturity and discipline, citing the structured routine of daily stand-ups and the need for punctuality as important preparation for work. Internships and placements helped ensure interns were prepared for their first industry job upon graduation and indeed the experience gained often gave them an important edge over their peers who had not had this opportunity: 'I just treated it as a 13-month-long interview' (G3).

Conclusions & Recommendations for Policy, Practice & Training

Our study addressed government, policy makers' and industry leaders' concerns that there is a digital skills gap among software engineering graduates in the UK. With employers increasingly requiring skilled workers with capabilities in areas like programming, data analytics and AI, we wanted to understand the character of any skill gaps amongst UK graduates in order to support training and development interventions. Our research was concerned with four questions: What were employers' experiences of graduate skill gaps, and how did this vary by the size and sector of the employer? Were these skill gaps technical or professional in nature, and how did this differ for graduates at different levels? What were the causes of the skill gaps, and what training could be done to address them?

Qualitative interviews were undertaken with employers from large multinational technology companies, public sector organisations and smaller SMEs, as well as graduates in their first industry role and a small number of industry stakeholders. These interviews explored participants' perspectives on the nature of skill requirements for work in software engineering and data science roles in industry and the public sector. In particular we sought to unpick the technical/digital skills

in areas like software development from the professional or 'soft' skills in areas like teamwork and communication. We explored what skills graduates were seen to bring to a role and what skills employers felt were missing or could be strengthened.

Our findings did not reveal substantial technical skills gaps. The employers recruiting UK graduates that we spoke to felt that widely applicable technical skills in coding and good foundations in maths and science were well represented in recruits. However, those technical skills developed through practical application, such as testing and containerisation, were less present. What concerned employers more were the gaps they perceived in recruits' professional skills. While their learning skills were seen as good, other skills needed for work in industry such as communication, teamwork, project management and commercial awareness were seen to be lacking. This was the case whether they were hiring BSc/Msc graduates or research graduates with a PhD. Our findings support existing research on skills (Yépez et al., 2023).

Importantly, perceptions of skill gaps differed according to employers specific requirements based on their sector or product, the level at which they were hiring (undergraduate or researcher) and their capacity to onboard and train recruits. Large companies with substantial recruitment and training programmes and capacity to support graduates were able to provide training on specific technical and domain knowledge, and professional skills. Smaller companies needed recruits to hit the ground running and were more likely to perceive skills gaps in their graduates. Most gaps whether technical or professional were associated with the practical application, and developing in software teams. Employers noted that these were not easily taught in UK HE. Graduates who had completed internships benefitted from this exposure to industry prior to entering the workforce, and were sought out by employers, several of whom ran their own internships programmes to support their recruitment.

Based on our findings, we recommend specific actions that employers and higher education institutions can take to better prepare students for industry roles. We suggest that employers, particularly SMEs with limited resources, would benefit from support in developing the professional skills of their graduate workforce through internship-like opportunities and training programmes.

1. Employers and HEIs develop opportunities for collaboration to design programmes and modules that embed practical teaching and industry-based case studies. This collaboration could be via forums, networks and workshops that bring together programme leads and employers' representatives involved in recruitment and training. Equally, collaboration could involve more targeted partnership between an employer organisation and a HEI who they regularly recruit from. The goal of these relationships and dialogues would be to explore

ways to embed industry practices though practical workshops and project-based learning.

2. Employers and HEIs collaborate to provide more, and more inclusive, opportunities for industry based placements and internships, so that larger numbers of students on a programme could take part in work-based training. As above, this would mean universities and employers forming closer partnerships to ensure internships are designed to fit with university schedules and supported by university structures.

3. Where organisations do not have the capacity to offer internships, they could consider investing in external training opportunities that focus on providing industry-relevant teaching of professional skills that could be useful to both HEIs and employers.

The Software Sustainability Institute will be launching a training programme that provides industry experience and training within an intensive 'boot camp' style short course. We will bring in industry experts to provide students with training and mentoring as we put them through their paces delivering a project in an industry setting. This training will offer employers vital support in training their new graduate recruits, and can also be offered directly to graduates to better prepare them for the workplace.

For more information about taking part in the training scheme, or if you would like to contribute your expertise as a trainer or mentor, please contact us via email info@software.ac.uk

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Appendix: Detailed Coding of Skills

Technical Codes	Professional Codes
Specific coding language	Communication
Specific domain knowledge	Being organised
Taking technology to market readiness	Adaptability
Foundation in STEM/SE	Public Speaking
Testing	Resilience in the face of change
Version control	Asking for help
Build systems/processes	Working in a team
Deployment	Learn how to learn
Cleaning data	Problem solving
Coding	Working with clients/stakeholders
Keeping up with recent technical developments	Inventiveness
Performance optimisation	Research Skills
Containerisation	Passion for subject/learning.
Using industry tools, frameworks and standards	Timekeeping
Engineering principles	Strong work ethic
	Working independently
	Being commercially minded
	Fresh perspectives
	Writing
	Responding to feedback/reflexivity
	Professionalism
	Drawing on experience
	Time/project management
	Agile/ways of working