RESEARCH DIRECTIONS

Bridging the skills gap in chemical sciences to train the next generation workforce

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Abstract

Chemistry is an inherently vocational discipline that sits at the interface of science, technology, engineering, mathematics, and medicine (STEMM) subjects (and those aligned with or informed by STEMM subjects). This article probes the perceptions of leadership in industry and higher education institutions (HEIs) in the UK and Ireland of the skills necessary for the next generation workforce, drawing conclusions regarding curriculum design and beyond.

Introduction

The chemical and pharmaceuticals industry is one of the best performing industries in the UK & Ireland and is fundamental to its economic success (Statista, 20 Dec 2023). Over 97% of manufacturing has a chemical input, and interestingly, the financial health of this industry has become a measure of the development of a given economy. For instance, in 2021, emerging from a global pandemic, the UK chemical industry had a turnover of £73.7 billion, with a gross value added (GVA) of £28 billion, positioning it as the second-largest manufacturing industry behind machinery and transport equipment (Cefic - UK, Key Facts, 2023).

In the 1990s it was noted that the training or education of chemistry employees would need to move away from a discipline-based approach and instead would need to follow a societal problem-based approach, suggesting a step change in the challenges faced by the chemical sector (e.g., renewable energy, climate change, food resources, Lagowski, 1998). Such complex societal challenges are recognised by the United Nations Sustainable Development Goals (UN SDGs) which were adopted by the UN in 2015 as a call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. These complex problems highlight the need for complex, multifaceted solutions, involving various stakeholders. What was first a possible mismatch between skills gained at university and those actually required in the world-of-work (Sarkar, 2016) is becoming a much broader and deeper challenge: chemical firms do not only require a highly qualified workforce but also a multi-skilled workforce (Rogalski 2006, Lewis, 2013) as some of the job roles in the chemical industries for the next 5 years and beyond are so complex they do not yet exist: 'To solve

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the challenges we face and find solutions to the climate problem, we are looking at almost a re-invention of the industry' – Marco Mensink, Director-General, (Cefic – The Chemical Journey, 2023).

The Royal Society of Chemistry regularly asks itself and its stakeholders what the future of chemistry should look like, with for instance studies in 2010, 2016 and 2023 published, evolving from looking at Skills first, then at the Future of Chemistry and finally linking Workforce and Educational Pathways together, stating that 'data lags and lack of granularity mean official statistics provide only a partial picture of how the chemistry workforce is evolving'.

As a team of chemists by training in academic/industry/charity settings, we are interested in understanding the granularity of how the chemical education landscape looks, including its end result, i.e., employable students. We sought to address this from two different perspectives, that of stakeholders in higher education institutions and that of stakeholders in the chemical industry and engaged in informal discussions with these two types of stakeholders, the analysis of which is discussed here.

Method

Heads of Departments (HoDs) of Chemistry delivering Royal Society of Chemistry (RSC) accredited courses were contacted via the RSC mailing list for HoDs directly by the RSC (followed by geographical region targeted emails to ensure a holistic spread of responses from the UK and Ireland). We contacted large chemical organisations via the Chemical Business Association, Chemical Industries Association, and ScotChem but also other individual industrialists in the chemical sector (followed by industry sector targeted emails to ensure a holistic spread of responses from the UK and Ireland). All responses were anonymised ensuring privacy.

There were responses from industry leadership (N=45) in various economic sectors as given in Figure 1 (i.e., the primary economic sector which involves the extraction and production of raw materials; the secondary economic sector which involves manufacturing; the tertiary economic sector which involves services such as distribution and transport, healthcare, and sustainable waste management and recycling; the quaternary economic sector which involves intellectual/knowledge services – inc. consultation, education, information technology, research, and development; and the quinary economic sector which involves specialized services - delivered by the highest level of decision or policy makers in government or industry).

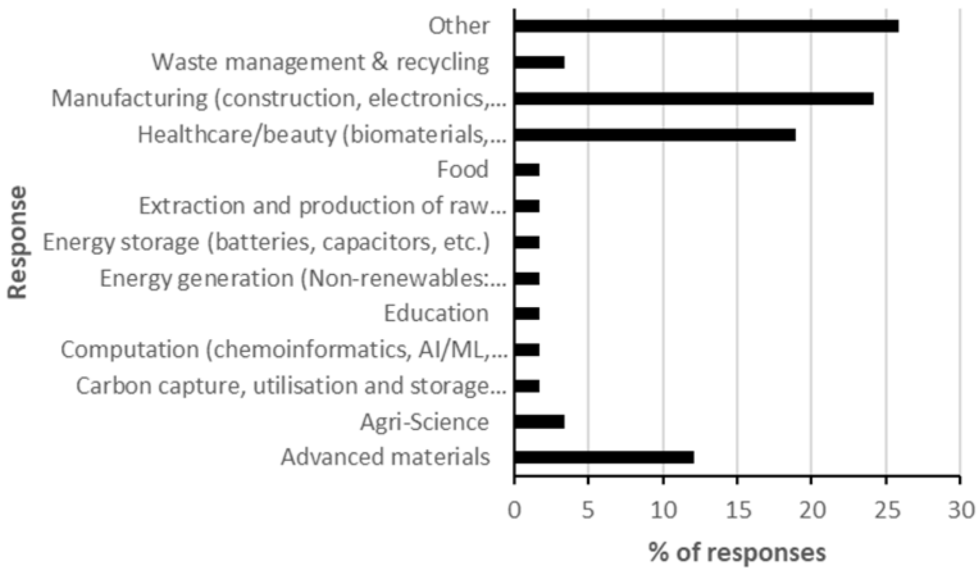

Figure 1 Primary focus of the industry leadership engaged with this study.

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The response rate from the academic leadership was approximately 41 % (N=25) from all geographical regions in the UK and Republic of Ireland.

Respondents were representative of the sector as a whole, with chemistry taught at level 5 (Foundation level); level 6 (Bachelor's or equivalent level); level 7 (Master's or equivalent level) and level 8 (Doctoral or equivalent level); and research carried out by researchers between levels 6 - 8 and postdoctoral level (See Figure 2 below)

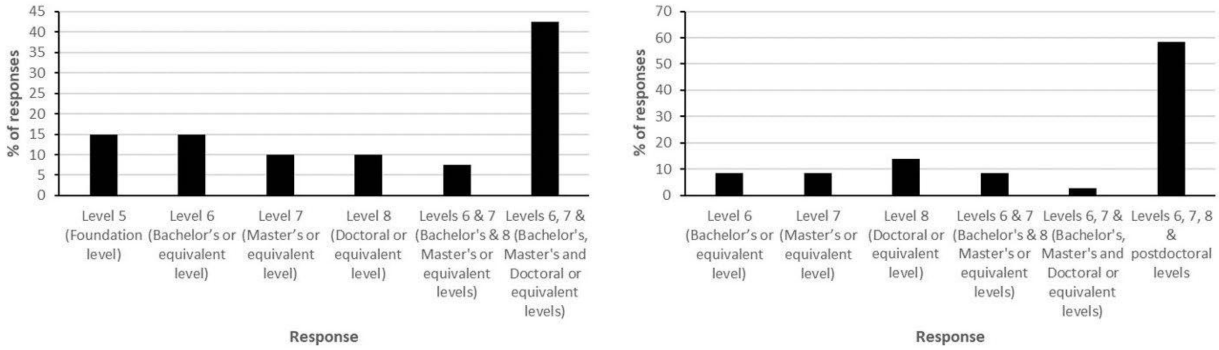

Figure 2 Level at which chemistry is being taught in HEIs engaged with this study

Results

1. **Talent Pipeline: Requirements - Recruitment - Skills**

Industries envisage hiring personnel with a wide variety of educational/technical backgrounds in the next 2-3 years, inclusive of personnel with apprenticeships, undergraduate/postgraduate qualifications and postdoctoral/industry experience. Some organisations make the choice to offer in-house training in chemistry to impart job-specific skills, however, this is not universal, and others rely on their employees to manage their continuing professional development (CPD) independently, some opportunities for which are highlighted in Training Opportunities, 2024.

In HEIs HoDs identify challenges related to recruitment to their undergraduate/postgraduate programmes, recognised as a nationwide problem in the UK and US (Plackett, 2019; RSC, March 2022; Boerner, 2024; RSC, 2024); for instance, as an illustration of the problem in the UK, the number of British students applying for and accepting placements in UK chemistry bachelor's degree programs dropped roughly 20% from 2015 to 2018 (see Figure 3, adapted from Plackett, 2019).

Recruiting and/or retaining chemists can be a challenge for the chemical sector, with specific issues identified including business experience/knowledge/skills (particularly soft skills, necessity for reproducibility & quality control, IP, etc.). The geographical location of the business, cognisant of the international nature of businesses, can also be an obstacle to recruitment or retention.

More specific concerns raised by the chemical industry leadership are around mismatch between level of qualification and nature of the job, with graduates being and feeling overqualified for a routine role (Lewis, 2013). For instance, the study from Hill, 2019 is interesting as it looks at UG perception of employability skills with 'with 30–50% students identifying they had developed five key skills: teamwork, thinking/problem solving, time management, laboratory/practical and communication skills, with a further 20–27% identifying organisational skills and around10% identifying independent learning/study skills'.

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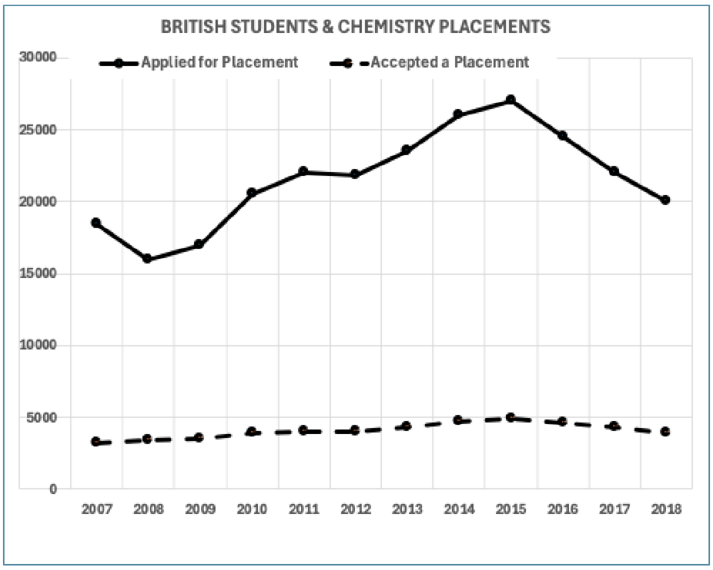

Figure 3 British chemistry students who applied for a placement. British students who accepted a chemistry placement between 2007 and 2018.

With issues related to student debt and graduates expecting positions better suited to their qualifications, vocational education has begun to enjoy a renaissance in popularity, with opportunities for vocational education programmes and apprenticeships to support the demands of innovation for such businesses (Rogalski, 2006). The UK government has been very keen to have an employers-led agenda for education via various platforms: apprenticeships entirely revisited in 2017, the launching of Institutes of Technology in 2019 and the emergence of new T-levels in 2020, with the clear ambition to grow productivity (DfE, 2021).

Our discussions with Chemistry HoDs suggest that HEIs grasp the needs of the chemical sector and want to prepare the graduates of tomorrow for future roles, ensuring high levels of employability for their graduates (similar to nowadays). This is supported by the Graduate Outcomes from Prospect for 2023_24 which gives Laboratory Technicians as 1st job destination for chemistry graduates and then Biological Scientists for the whole UK, with 49% working FT in the UK after graduating with a 1st degree, and ca. 23% as science professionals (inc. the Lab Technicians and Biological Scientists mentioned above) (Prospect, 2023).

There is a general consensus about what applicants (will) require when applying for positions in the chemical sector, including: understanding of health & safety regulations; versatile practical laboratory training; the ability to analyse large data sets; understanding of chemical processes; understanding of complex chemical problems in their entirety (including societal and business perspectives, e.g., circular economy; an area employers noted was an opportunity for improvement); the ability to work with other disciplines or with non-scientific stakeholders; the ability to be curious, innovative, and creative; social and ethical awareness; an appreciation of sustainability. As examples, it is noteworthy that some HEIs have already launched Level 6 or Level 7 (BSc or MSc) courses demonstrating their commitment to addressing the 21st century issue of Sustainability (Universities, 2024) and with others recently reviewing what the knowledge framework for green and sustainable chemistry is (Gunbatar, 2024).

Less important were an understanding of good clinical/laboratory/manufacturing practice (GCP/GLP/GMP, respectively) regulations; experience in automation (although industry noted this is an area of expansion); proficiency in using chemical software; or an ability to code, potentially because these are either likely to be covered by in-house training to ensure compliance with job-specific requirements or very specific specialist skills sets (e.g., coding and/or software proficiency).

When asked more specifically about the need for coding skills, although it is not vital for industry there was a preference for Python coding skills also observed in the Benchmark Statement for Chemistry as published 2023 (QAA, 2022) with graduates expected to 'choose and deploy methods for data analysis and manipulation, potentially including coding and scripting, for presentation, communication and problem-solving purposes', demonstrating consensus between industry and HEIs.

It is clear from our communication with the chemical industry that they understand which knowledge / skills they want recruits to possess in the short, medium and long term. The emerging skills described in Deloitte, 2021 (digital systems, robotics and AI in aerospace; new laboratory and technician procedures for experiments; new software for analysing scientific data; new coding languages or other programming software) are of some importance to the chemical industry leadership, and such skills seem key to some jobs roles in the chemical industry of the future (Table 1, adapted from Deloitte 2021).

Chemistry Curriculum: Current State - Requirements - Solutions

HEI curricula prepare chemistry students for teamwork with opportunities for team-based learning activities (a compulsory element of RSC accredited courses), and instil the need to be curious, innovative, and creative via various methods of assessment. Industries identify opportunities to enhance curriculum content to include understanding around IP, business skills including commercial awareness; broad practical experience in line with industry requirements (e.g., understanding product development); and soft skills.

Whether such skills can be easily delivered by the HEI sector is dependent on their staff roster (it is uncommon for academic staff to have significant industry experience) and RSC accreditation guidelines. Some HEI departments have an industrial advisory board which provide employers/industry an opportunity to influence course design and delivery; opportunities for student participation in work experience (high impact learning activities); current chemistry-focused Knowledge Transfer Programme projects; staff given the support/freedom to engage in consultancy work with chemical industries; opportunities for engagement with chemical industries via support for attending conferences/networking meetings, etc.; with access to local Science Parks as an area for potential improvement (Dolan, 2020).

The complex real-world problems faced by industry necessitate the application of multi-disciplinary, inter-disciplinary, and trans-disciplinary approaches to solving those problems which educational establishments recognise (Hardy, 2021). The general agreement is that: (i) societal challenges for the chemists of the 21st century include sustainability, climate change, AI & data, energy & food security, health & wellbeing to provide the human pipeline of 'Sustainable Specialists' forecast by Statista as the 2nd fastest growing job between 2023 and 2027 (Statista, 2024); (ii) organisations should be concerned with the political, economic, sociological, technological, legal, and environmental (PESTLE) external factors for its teaching practice; (iii) that chemistry learning should be intertwined with that of other subjects (particularly science, technology, engineering, mathematics, and medicine [STEMM] subjects) in line with RSC accreditation.

HoDs note that 'attempts are made to include real-world scenarios'; 'we start building new approaches for holistic understanding of chemical challenges'; 'our course is very strong academically but industrial relevance may be less beneficial', with some HoDs noting provision of specific modules on business and circular economy in place, or delivery of case studies which places the subject in its wider context being part of final year students' studies (L6 or L7), or existing within options or larger school modules'.

There is recognition of opportunities for curricula to be updated (in line with RSC accreditation) to address industry needs in a volatile period in the HEI sector (Boerner, 2024; Irish Times, 2024, OfS, 2023, HoC, 2024).

Table 1 Examples of job roles and requisite skills associated with jobs in the chemical industry.

JOB	OVERVIEW	REQUIRED SKILLS
Computational materials scientist/engineer	Applies computational methods to understand/predict the properties of materials.	Appreciation of in silico techniques applicable to modelling materials across length and time scales (including but not limited to quantum mechanical methods, molecular mechanics, continuum methods).
Digital twin scientist/engineer.	Creates virtual representation of processes/products to facilitate understanding and optimisation of products during their development and application.	Computational modelling, and data science (including insights from artificial intelligence and machine learning).
Energy materials scientist/engineer	Applies chemical methods to prepare, characterise and apply materials for energy generation/storage.	Synthetic and analytical chemistry techniques (including electrochemistry), computational modelling.
Nanoscale chemical scientist/engineer	Applies chemical methods to prepare, characterise and apply nanoparticles/materials.	Synthetic and analytical chemistry techniques, computational modelling.
Supply chain management	Identifies opportunities and challenges related to supply chains necessary to ensure successful	Data and management science (including insights from artificial intelligence and machine learning).

2. Current Views of Chemistry Education: Challenges - Potentials

It is very apparent that despite the contrast highlighted above between the two leaderships (academic and industry), there are also some common threads to their views: (i) recruitment of chemists for either graduate roles in industry or postgraduate degrees in HEIs is an issue for both parties, and that is also linked to geographical concerns; (ii) teamworking is important to both parties, and is provided by RSC-accredited courses; (iii) requirement to be curious, innovative and creative seen as fundamental for both parties; (iv) common understanding that local and more specific in-house training is a necessary addition to undergraduate training, specifically around regulations or health and safety matters.

Traditionally the chemical sector has been a reliable and safe sector to be part of, until recent years where it has been facing substantial challenges and a very fluctuating environment. Therefore, a bigger understanding of where chemistry stands in the socioeconomics of a country - its PESTLE - is crucial to all involved, and more specifically the academic community and the talent pipeline that it generates (while some academic research projects address social, ethical and historical perspectives this is not universal, and it would be more reliably delivered via RSC accreditation necessitating curriculum provision that offers a fuller appreciation of the current societal challenges and social & ethical responsibilities to the whole cohort of students). Vocational training, whether through an apprenticeship or through another mode of part time study while working, offers a clear advantage in relation to this, and could be a source of inspiration for more traditional learnings of Chemistry. Being in the workplace from day one of their training, vocational learners are embedded in company culture, ethics and values from the outset. This enables them to view all of their training, whether that takes place at work or off the job (e.g., at an HEI), through the lens of societal impact and develop that way of thinking at a very early stage in their career. This is in contrast with full time students who may encounter this way of looking at their work at a later stage in their studies, as a 'bolt-on' to their studies if it is covered in a specific module, or not until they actually enter the workforce.

There are very few mentions from the academic leadership of the teaching of circular economy / supply chains, parallel to that of chemistry; this seems to be a missed opportunity. The generation who are currently considering their future careers are conscious that they want to work in industries that do not have a negative impact on the environment, society, etc (Dobbelaar, 2021). Including teaching on topics such as circular economy would help position chemistry courses as equipping young people with the skills to 'make a difference' or a positive impact in society and may increase interest in them. Since industry experience of staff in HEIs (e.g., through previous employment) is limited and could therefore be a limiting factor, challenges faced by chemical businesses around productivity, access to supply chains and the circular economy are opportunities for future academic investment.

However, the work of attracting students to chemistry programmes cannot be undertaken solely by HEIs if it is to be a success; the primary and secondary school curricula should be enhanced with modern examples to help students understand the applications of what they are learning at school, and how it can be applied to address global and social challenges (Langin, 2018, Palmer 2022). It is noteworthy that in 2019 a joint advisory group to the RSC, Royal Society of Biology (RSB), Institute of Physics (IOP) and the Association for Science Education (ASE) was established, known as the Primary Curriculum Advisory Group (PCAG), with the goal of producing advice/guidance about the future of primary science curricula (Turner, 2023); indeed, the Framework for a Future Primary Science Curriculum report supports evidence-based relevant, contemporary and future-proof primary science curricula, that should help prepare children to understand their world and concomitant individual/societal needs in local/global contexts. Moreover, the RSB, RSC, IOP and Hachette Children's Group have launched a new educational book series "Your expert guide" to introduce children (ages 8+) to the foundations of biology, chemistry, and physics (Hachette, 2024). The concept of interdisciplinarity can also be introduced at this stage, so that students understand that scientists of particular disciplines rarely work in isolation (particularly in industries developing products/technologies to address complicated global challenges). In combination with engaging careers advice (as already known to be important - Galloway, 2017), whereby young people are exposed to the diversity of roles in the chemical sciences, and the different routes into them, the perception and reputation of the chemical sciences may be improved, which could encourage more young people to pursue a career therein. For instance, the Chemical Business Association (CBA) has been actively working to address the current perception of the chemical industry. To counter the negative perceptions, it has introduced a number of initiatives designed to challenge current attitudes and raise awareness of the numerous and exciting opportunities within the sector. These have targeted both the younger generation, alongside talent from other sectors, with the aim of showcasing the chemical supply chain and highlighting the vital role it plays in society, economy and in solving complicated sustainability challenges. One such initiative is the CBA Future Council, established in 2022 and comprising young people from a variety of backgrounds and roles across the CBA membership, the Council aims to find new ways to raise awareness and encourage new talent into the industry. Another CBA initiative is its People & Skills Hub which is working with stakeholders, including Government, education partners and its members, to highlight various career paths, training opportunities and support networks within the industry. In 2023, the CBA staff and members of its Future Council, arranged and participated in 25 events at schools, universities and career venues, directly meeting and talking to over 16,500 attendees about a career in the chemical supply chain. This momentum is in contrast with the 2016 study in Australia that looked at 'Graduate Employability: Views of Recent Science Graduates & Employers' where the notion of building relationships between industries and the university appeared in only 14% of employers' comments (Sarkar M., 2016).

In the same vein of looking at building partnerships, HEIs could look to engage with programmes such as the Education & Training Foundation's Industry Insights programmes (ETF, 2024), which are designed to support staff involved in the delivery of T Levels upskill and increase their understanding of industry through placements in industry. While this particular scheme may not be open to staff at HEIs, perhaps individual institutions could look to their industrial advisory boards or wider professional networks to organise similar opportunities for their staff. These could include workshops on particular aspects of translating the taught curriculum to 'the real world', longer term sabbaticals or research placements in industry to help refine the curriculum to meet the needs of industry, or even an industry-academia exchange to foster a more collaborative approach to programme development.

3. Implications in shaping the chemistry workforce of the future

Based on our understanding of the chemical educational landscape and its (future) employability, there seem to be two main implications, that go much beyond what was recommended 15 years ago (Hanson, 2010), and very much align with the fact that 'it is likely the type of chemistry jobs will change' as recently established by the RSC (RSC, 2023). Implications from the work presented here are two-fold:

CURRICULUM-BASED

There is a need for a PEDAGOGY shift around two key aspects:

TRANSDISCIPLINARITY in chemistry curricula is required and can be used as a strategic lever to reshape chemical education to bridge specific skills gaps. However, interdisciplinarity is only mentioned once in the Chemistry Benchmark 2022 (QAA, 2022) and tends to be perceived as the juxtaposition of sciences as opposed to embracing a wider, integrative approach to solving societal challenges. It is accepted as being crucial to problem-solving, yet it cannot be successful in an aggregated juxtaposition of pre-existing modules. Instead, it requires updated curricula using an integrative approach whereby chemistry core elements are taught within a context and with a purpose. That synthesis of content as a pedagogic strategy requires investment in the training of the staff themselves in direct partnership with industries for that pedagogy to be effective and impactful. This paradigm shift requires a cultural change within academics, and we predict that this change will be challenging to implement (although there are signs of similar conversations having taken place elsewhere - Sarkar, 2020). Indeed, as established in (Schijf et al., 2022), one of the 6 elements for interdisciplinary understanding requires the 'knowledge of different discipline paradigms'.

SOFT SKILLS & COMMUNICATION SKILLS need to be robustly and deeply embedded within curricula, not as an add-on, on the side of other learnings. Indeed, in (Beccera, 2021), it is suggested that 'moving forward, institutions of higher learning should consider focusing on fostering [...] courage and resiliency in students while also stressing the vital importance of ethics. Meta-learning, the ability to reflect and adapt to change, should also be a priority in higher education'. That is an interesting pedagogic challenge for academia whereby building resilience, well-being and curiosity will require well thought-through tactics to engage, question or defy students' attitudes to changes and uncertainties, without challenging their mental health or well-being. Considering attitudes will be important indeed as a recent work from (Reid, 2020), link beliefs and attitudes to academic motivation.

People skills are and will likely remain critical in future with teamwork is given as key in (Beccera, 2021; Cefic – The Chemical Journey, 2023; DfE, 2022) to addressing complex problems and needs to be taught in a much deeper and coordinated way between academia and the world-of-work (a good example of this could be the Service Learning, or Chemistry for the Community, as unrolled and monitored in Maine and New Hampshire, US - Bowe, 2023). In the same vein, McKinsey & Co., 2020 highlights that the need for partnership and collaboration will be fundamental to bringing flexibility and optionality in a sector that goes towards smaller, more flexible production units as already adopted by pharma companies.

Communication skills are seen as a crucial modern way of adapting to new situations and to new communication methods to convey key people skills such as sensitivity and empathy, and also to adapt to diverse environments and people (Beccera, 2021; DfE, 2022). Self-reflection is seen as key for self-assessing one's work and for communicating around that topic with others for maximum productivity (Schijf, 2022; DfE, 2022). Very importantly, using such multifaceted communication skills for the production of robust scientific data will help with minimising public misinformation and support its understanding on key societal issues (DfE, 2022). Finally, strong human skills are viewed to bring a competitive advantage in a world moving towards automation and machines (Beccera, 2021).

When it comes to developing soft and communication skills, apprentices and other work-based learners have an advantage over those in full time study, as they are working alongside a diverse group of colleagues and having to develop and apply these skills, such as team working and communication, from day one. Being at work will also support them in developing their resiliency, exposed as they are to the genuine pressures of the working world, whether that be receiving challenging feedback on the quality of their output, experiencing redundancy or restructuring, projects being shelved or pivoting at short notice, meeting the behavioural or cultural expectations of the workplace or difficult interpersonal relationships, for example. As such, rethinking and reshaping the HEI environment and creating both a more diverse and nurturing experience for the learners may become very beneficial indeed in developing such skills, in direct alignment with the OfS requirement for a successful student experience and outcome.

That is also why there is a clearly articulated requirement to foster CURIOSITY and IMAGINATION in today's learners, with an overwhelming positive response from the industry leadership to the need for these traits in the future workforce, with HEI leadership attempting to instil that need in their learners via research (including opportunities for personalized/student-centred learning).

It is reassuring to see that the chemical industry places high value on traits such as curiosity and imagination. Balancing the time required to deliver the robust underpinning chemical science knowledge and transferrable skills desired by employers in addition to supporting students to develop these traits could pose a challenge for HEIs; however, degree programmes that require students to undertake an independent research project are well-placed in this regard. Perhaps this foundation can be built upon by facilitating more encounters with post level 6 cohorts within an HEI who are actively involved in research. These conversations could help undergraduates to understand the unpredictable nature of work in chemical science and the need to be able to reflect upon and learn from unexpected outcomes and potentially pursue new lines on enquiry based on these, as already established as important in studies by Belt, 2013 & Overton, 2016. In the apprenticeship landscape, there has been a move towards a policy whereby funded qualifications delivered as part of an apprenticeship programme can only deliver the knowledge, skills and behaviours required for that particular profession and no more. With this in mind, it is important that the occupational standards upon which apprenticeship programmes are designed do not neglect to include, or understate the importance of, the behaviours of curiosity or imagination. If they do this, there could be a situation where those who have taken an apprenticeship route into the profession are less well equipped to innovate than those that took an academic route, and as a result are left behind as technology or business priority areas move on.

Moreover, research is undertaken by industry at various scales (from SMEs to multinationals) and their need for curiosity, creativity and imagination lies everywhere: when delivering innovation into a process, a production line, the optimisation of a product.
With others strongly arguing that for the next generation to survive in a world of intelligent automation, we should be emphasising the learning of soft and artistic (creative) skills (Ma, 2018) that message should be even more evident in the most creative of all sciences, in a chemistry sector currently being completely redefined:

‘We sometimes tend to think that life is a linear evolution. It is not. The driver is imagination, and this is what will drive us to the future. What has been true for the last 50 years in terms of developments and methods, notably on chemistry, are not necessarily what is needed and how it will happen in the next 50 years. Where we will be in 50 years is therefore unpredictable. We need to have trust that the imagination will create the path for the future and faith that this path will be the right one.’ Prof. Ari Koskinen, Emeritus Professor, Aalto University, Helsinki (Cefic – The Chemical Journey, 2023)

This need to think and act differently has already been adopted by others (Isaacs, 2023), but also the Chemical Business Association who have launched Generation STEAM, an initiative geared towards engaging more young talent with the industry and highlighting the diverse entryways and careers available throughout the chemical sector. This recognises that the chemical supply chain requires a wide range of skills, not just traditional STEM (Science, Technology, Engineering, Maths), and the addition of the letter ‘A’ stands for Art, also for words such as Attitude, Ambition, and Ability. Generation STEAM is about being fully inclusive and to create diversity, to widen our thinking and to open our industry to a wider workforce that may have thought it wasn’t for them.

‘Generation STEAM reflects the need for creativity and innovation within the chemical supply chain and thus attracts a broader spectrum of talent that the industry needs in today’s world, especially as AI only continues to rapidly evolve and expand’ (Doggett, 2024).

PRACTICE-BASED
Noting that the Membership of the Advisory Groups for the Subject Benchmark Statement for Chemistry in 2022 is made of 18 individuals, with academic representation at ca. 72% (13/18), QAA’s at 11% (2/18), RSC’s 11% (2/18) and industry accounting for only ca. 5% (1/18), it seems an obvious place to start with establishing a working group to redefine membership in a more representative way and then rewrite the benchmark statement accordingly. This could be a stepping stone within the policy recommendation as made by the SCI in 2023 in its manifesto for the ‘Creation of an Innovation & Science Growth Council, including chief executives of large science-based businesses, university representatives and start-ups. This body would have a direct reporting line to the prime minister, making sure science industrialisation is at the heart of government policy.’ (SCI, 2023).

Innovations in HEI curricula could begin at level 7 (Masters) where the risk for any HEI engaging in development is minimised (owing to the fact they are shorter programmes than level 6 courses, with smaller cohorts, making it easier to manage engagement from industry partners) while supplying skilled graduates to the chemical industry. This could take the form of a pilot scheme at MSc level where Chemistry is taught in an integrative way, with a newly found liberal arts & science dimension and with case studies at the heart of the learning. A pilot scheme would help minimise this risk and give time for institutions to broker robust relationships with its employers in the chemical sector.

The establishment of a working group for the redefinition and reorganisation of academic structures. In the US, the approach has already been taken with the creation of new interwoven Colleges (e.g., the College of Sciences and Humanities; the College of Health and Education; the College of Business, Innovation, Leadership and Technology), thus recognising and rewarding interdisciplinary learning as an innovative way forward for higher education (Becerra, 2021). The UK, despite a few successful examples (LIS; UA92), seems to be lagging behind in that respect (Schijf, 2022). Although there are examples of partnerships or networking in the chemical sciences going in that direction (UKRI ICCE; RSC Events, 2022), we believe that HEIs, IoTs or FE colleges could consider whether reorganising themselves in order to provide novel multidimensional programmes and educational opportunities is taking a risk or is instead creating a robust competitive advantage in the long run, within a more and more globalised and pressurised educational market?

Conclusion

Through discussions with two types of stakeholders, this study aimed to examine the views of industry-based and HEI-based leaderships in the chemical sciences in the UK and Ireland, regarding the skills necessary for the next generation workforce. There are some common views between the industry-based and HEI-based leaderships, e.g., recruitment of chemists in either graduate degrees or in chemistry jobs is an issue; teamwork skills; requirement to be curious, innovative and creative seen as fundamental for both; local and more specific in-house training is additional to existing graduate provision, specifically around regulations or health and safety matters. There is recognition that the needs for the workforce of tomorrow are different to the past, with opportunities for industry-based and HEI-based leaderships in the chemical sciences to work together around programme development locally/regionally/nationally/internationally. We hope that this manuscript will stimulate further engagement between the leaderships and curriculum development in the chemical sciences to ensure the next generation workforce has relevant skills necessary for the 21st century.

Authors Contributions

CCE and JGH have similar interests in the employability of their chemistry students and worked together on this study, contacting targeted mailing lists, and discussing the results. TD and KDH were subsequently invited to collaborate on this manuscript, to bring their perspectives to the results and implications sections.

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Conflicts of Interest

There are no conflicts to declare.

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