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Calibrating future curricula

Executive summary

This work is part of the Engineers 2030 project by the National Engineering Policy Centre (NEPC), led by the Royal Academy of Engineering. In line with the NEPC's education policy for skills and its associated six principles, Engineers 2030 has two main aims. Firstly, to identify how engineering knowledge, skills and behaviours are changing in the 21st century, and the extent to which those changes enable engineers to exemplify principles, such as being socially responsible and inclusive, data and digitally fluent, and trusted agents of the public good. Secondly, to identify what is needed to educate and support the engineers and technicians of the future. The goal is to do this in a way that attracts young people into engineering careers to collaborate on creative solutions to pressing problems while ensuring that risk is mitigated in all its forms.

The messages emerging from this research, which interviewed over 40 graduates who are now in engineering employment, were complex and challenging, yet they nevertheless supported the NEPC's vision and principles.

Engineers acknowledged a longstanding mismatch between the abstract or heavily theoretical nature of many university engineering education programmes and the practice-based knowledge and skills developed during working life. This includes programmes where significant effort had been made to develop work-related skills. However, they recognised the inevitability of this mismatch: a university degree's primary aim (degree apprenticeships being a notable exception) is to socialise students into engineering domain specialisms while engineering companies aim to build on, and go beyond, that foundation. They cultivate knowledge of work processes and skills so that engineers can create solutions that work technically, environmentally and commercially. Participants nevertheless felt that more could be done to minimise this mismatch, especially in relation to digital and on-site practical skills. Both recent recruits and more experienced engineers identified these as vital to the modern profession but with an insufficient presence in university engineering education. Both parties suggested that, given the recent and ongoing advances in machine learning (ML) and generative AI as well as the increasing focus on sustainability and ethical issues, the way forward may be to identify and share best practices that support engineering students and practicing engineers to work in the physical and digital worlds and at the interface between them. This would help academia and industry to appreciate their respective contribution to this critical issue.

A desk-based review of providers with a high-level of information available has supported these views. It also suggested that non-technical skills are typically evident in only a small number of specialist modules and that these predominantly align directly with the outcomes required by Accreditation of Higher Education Programmes (AHEP).

Introduction

The NEPC envisions the development of an engineer's skills as a two-fold process that considers both 'what' and 'how'. The 'what' is the definitions of skills, the source(s) of the definitions, and when they were defined. This is important because the source of the definition will predispose curricula to be more or less likely to be teaching skills that industry deems emergent.

The 'how' issue concerns curriculum design: via single subjects or elements of integration; considering the model of skill delivery as standalone, partially embedded or totally embedded; in relation to curriculum design, and pedagogy, through transmission, dialogic, problem/project-based methods. The relationship between them is vitally important because the taxonomy would show skills and their context of delivery. This analysis will allow the academy to: a) analyse employers' reports etc. on skills in a more nuanced way – for example, are they taking account of how universities deliver skills or just presenting them with lists of what they are looking for? And b) talk to employers about skills and how their employees learnt those skills – for example, do they think that project work is learnt as a skill more effectively through in-curriculum project-based learning, for example, or as a standalone module on the principles and practices of project work?

The first phase of the research programme seeks to understand what skills the UK higher education system delivers to engineering graduates. This includes an investigation of the core elements that define current UK higher education engineering syllabi. This aims to identify the skill set that engineering higher education courses provide for their students through in-curricular activities. This research was conducted as a desk-based study of published engineering curricula within the UK. A particular focus was on design and project modules where skills are commonly defined.

Industry's requirements now and in the future cover knowledge, skills and behaviours. While these are impossible to separate completely, the study presented here takes a deliberately skills-focused approach. Through the collection of a rich data set, it aims to uncover graduates and industry's views on what knowledge and skills practicing engineers use in their day-to-day jobs. Despite this predominantly skills-based lens, the research also addresses the issue of knowledge that may have value to engineering skills or the careers of future engineers, as well as the behaviours that display specific skills.

To address the research question concerning which skills are most or least useful to professional engineers, the authors conducted interviews and focus groups with practicing engineers – predominantly recent graduates (one to six years in practice). In the discussions, participants were also asked to reflect on how their skills were acquired – in the classroom or through practice – and the enablers for skill acquisition.

Analysis of the current curriculum

This study aims to indicate the skills that higher education institutions in the UK seek to deliver to engineering students. It should be noted that, as this study draws from publicly available curriculum information, it can only uncover the stated outcomes of a module or programme.

The work aims to investigate the core additional elements that define innovative UK higher education engineering syllabi – for example those that seek to go beyond the baseline specified by AHEP4. Analysis of the existing data will particularly focus on the design and project modules where skills are commonly defined.

Introduction

The authors developed an inventory of skills relevant to engineering practice, not including standard teaching elements of engineering degree courses. They then individually searched for these terms across higher education institutions that provide detailed module descriptions. Four disciplines were considered: chemical engineering, civil engineering, electronic/electrical engineering, and mechanical engineering. The authors then recorded the module in which they feature and calculated the overall frequency by engineering discipline.

Searches were made for 16 different skills:

- Communication
- Digital (specifically programming)
- Ethics
- Risk management
- Independence – covering judgement, learning, research, work
- Interdisciplinarity
- Working knowledge development
- Site skills
- Leadership
- Legal
- Policy
- Problem-solving
- Sustainability
- Teamwork
- Work ethic

Findings

Certain skills did not appear at all: work ethic and knowledge development. Although valuable, these are perhaps inherent characteristics of individual students and institutions' pedagogic approach. They could be further developed or refined, but if this is the case it is not mentioned.

Communication: only two institutions failed to mention communication at all. Where communication skills were mentioned, these were often embedded in introductory modules in year one, or non-lecture-based modules, particularly project-based work.

Digital skills were treated as strictly programming. There is a high prevalence of this skill across institutions, with only one exception and this is likely to be due to limited information on their publicly available programme specification documents. Across disciplines, chemical engineering was where programming instruction was conspicuous by its absence.

Ethics: apparent across all but one institution, ethics typically features in introductory year one courses, projects, and also in more specific modules covering areas such as 'biomaterials' or 'renewable energy'.

Independence: here the focus was on individuals' practical capacity to operate on their own with respect to judgement, learning, research, or work. Such independence featured heavily in project work, and to a lesser extent as an element in introductory modules. It was not a feature of around one-third of institutions' programme specifications.

Interdisciplinary working: far from a ubiquitous feature of engineering education. In total, five institutions made no reference to it in their materials. Furthermore, in several cases where it was mentioned it had a peripheral position in the curriculum. Its sole appearance was in the year three module 'mathematical physiology'.

Where it had a more central role it was often in projects and courses where the emphasis was on design, such as applied design and practice (year one), integrated building design, scenarios in civil engineering, and fundamental biosciences (year four).

Site skills: only a feature of six institutions' provision, principally as part of civil engineering practical/project work. However, one institution offers it as part of a bioenergy module available to chemical engineers.

Leadership: a feature of nine institutions' provision and often a feature of modules concerned with management/business, such as innovation, entrepreneurship and enterprise or business and project management.

Legal: only three institutions made no reference to legal aspects. Where it occurred, it featured in project modules and those focusing on management and enterprise, such as institution 13 module finance and law for engineers (year three). It also occurred in areas touching on potentially sensitive ethical issues, such as biomechanics and biomedical engineering and forensic bioengineering.

Risk assessment: three institutions did not mention risk assessment. Where it did occur, it featured as an element of project work, or highly specific modules generally taught in later years in the degree programme, such as 'advanced safety and loss prevention' (year four), or 'disaster resilience and sustainable development' (year five).

Policy: modules that introduced policy or considered policy issues were offered by 10 institutions. These were generally found in modules offered from year three onwards, and concerned highly practical applications, such as 'business economics' (year three), 'energy studies' and 'sustainable transport' (years three and four respectively). Two exceptions where policy was a concern early on where it features in year one modules 'engineering principles/practice' and 'engineering: impact assessment'.

Problem-solving: a generic skill, or one with multiple applications, was referenced by all institutions. It frequently featured in modules concerned with engineering practice or aspects of design, such as 'engineering by design' (year one) or 'engineering practice' (year one), along with programming, 'programming fundamentals for engineers' (year one), and mathematics, 'mathematics for engineering and the environment' (year one).

Sustainability: offered on modules by all institutions, and covering almost all disciplines. When it was absent, it was most frequently in the case of chemical engineering.

Teamwork: offered on modules by all institutions, and covering almost all disciplines. When it was absent, it was most frequently in the case of chemical engineering.

Group work: note that teamwork has been alternatively used as group work.

Summary

The authors recognise that it is highly likely that many of the aspects identified previously do feature within the curriculum, but it is telling that they are not explicitly stated in published course descriptions. It is also notable that where similar work, specifically focused on sustainability content[1] in the curriculum and undertaken in 2022, found many gaps in provision, this work two years later suggests coverage is now more extensive. This is highly likely to be the impact of new requirements of accreditation in the form of AHEP 4.

1 Review of the teaching of sustainability in UK engineering higher education, RAEng https://raeng.org.uk/media/i2giclyr/engineers-2030-review-of-the-teaching-of-sustainability-in-uk-engineering-higher-education-march-2024.pdf

Transforming engineering education: recommendations from graduates

According to recent graduates, the education received during their undergraduate and postgraduate studies provided a valuable, if insufficient, foundation and covered the fundamentals necessary for practicing engineers. Having an engineering degree was valuable and opened doors for jobs.

> It does help kind of set the foundation or a foundational box.
> **Beatrice**

Nonetheless, engineering education is therefore perceived as too theoretical and removed from the reality of the workplace. The educational methods graduates were exposed to during their studies has led to this perception, as they conveyed primarily an understanding of engineering as a siloed and static field, while in practice engineering is interdisciplinary and dynamic.

> You come out of university with a lot of theory in your head and you're like 'oh, everything's gonna be like this'. Then you actually go for the role, and it's not.
> **Simon**

The evolution of engineering degrees has always been a critical endeavour and requires aligning academic outcomes with the dynamic demands of the industry and society. Based on the comprehensive insights gathered from engineering graduates, several key recommendations emerge to enhance the efficacy and relevance of engineering programmes. These recommendations are pivotal for cultivating the next generation of engineers equipped to tackle contemporary challenges with innovative and societally conscious solutions.

Greater and more consistent integration of real-world professional experience within the curriculum and the development of profession-oriented skills can be achieved through actions such as:

- collaborations with industry and community partners
- active learning
- exposure to interdisciplinary practices
- a shift towards more flexible and student-centred degrees (those that privilege student activity through projects etc. reducing teaching-centred content delivery, or students having the possibility to select courses aligning with their future professional interests or narrower specialisations)
- an emphasis on lifelong learning and continuous professional development.

Strengthening links between universities and industry and community partners

Graduates emphasise that the gap between theoretical knowledge and practical application can be bridged by fostering robust and extensive partnerships with non-academic stakeholders. In current times, engineering programmes are functioning in diverse and active ecosystems, in which they are one actor alongside many others, such as industry (both small and large enterprises), local communities and organisations. The continuing challenge for educational institutions conferring engineering degrees is to create socially robust knowledge and educational activities together with the communities it is part of and the actors it interacts with. This increases universities' aspirations that, upon graduation, students become valuable contributors to society.

The strengthening of the interaction between engineering programmes and external partners exposes students to problems of societal significance, as well as to the methods, tools and skills relevant for their profession. Furthermore, this strengthens students' ability to apply theoretical knowledge in practical settings, fostering a deeper understanding of their field. Industry and community partnerships can guide curriculum development to ensure alignment with current technological advancements, societal challenges and market needs, thereby enhancing the employability of graduates.
The partnerships between engineering programmes and industry and community actors can manifest in various forms, such as:

- **Internship programmes and work placement**: extending the provision of structured initiatives integrated in the engineering curriculum will allow students to gain hands-on experience in real-world settings, enhancing their practical skills and understanding of industry expectations. Graduates credited internship programmes and work placements as having provided one of the most formative educational experiences as future professionals.

> The truth of the matter is that actual industry experience has a lot more value than whatever can be taught in university, because industry really appreciates that you have been able to go out in the real world and actually take real-world responsibility and do things. The closest thing universities can do are internships and placement years.
> **Dimitrios**

Nonetheless, not all participants have had the opportunity to be involved in such programmes as part of their degree, and for some it has proved extra difficult to secure an internship on their own.

- **Community- and industry-sponsored projects and competitions**: enhancing company and community-sponsored projects and competitions by designing them to reflect pressing local concerns, to offer students practical problem-solving experiences and exposure to current issues.

> Exposure to a more like a real-life project, maybe a slightly longer-term project over more than two months, would have been interesting; a longer-term project with more input from industry would have been helpful.
> **Alice**

> I joined the Engineers Without Borders and the designer got external people to come in and present to us a real-life case on [a lower- or middle-income country], and we're supposed to build a prototype to improve one aspect of their life. You're thrown into a room with teams of people you've never met before. It's very much interdisciplinary.
> **Gannika**

Site visits: providing students with an opportunity to step out of the classroom and into actual engineering environments, students gain invaluable insights that lectures and textbooks alone cannot provide. Giving students access to a diverse range of engineering sites and locations has been highlighted as an experiential learning experience that has immense potential to develop practical skills, as well as an understanding of how different technologies or equipment function and how theoretical knowledge can be applied, especially when it comes to following safety guidelines and regulatory compliance.

> What we learn in academia is different from when it comes to a job. So I would suggest to get more site visits, without seeing just in the picture, a presentation, or a theory. That won't be enough to understand what all things are inside a control valve or how it is working, and what are all the parameters to identify.
>
> **Inaya**

Several graduates recounted having felt unprepared for this experience. This gap has been particularly striking for graduates working in the civil and chemical fields, who received little to no training during their degree about what it means to do site work or had little understanding of the appearance and scale of the locations or of the equipment used. Pre-visit preparation and post-visit reflection emerge as essential educational components complementing site visits.

> I don't think anyone can be prepared for it until you get there, for the sheer scale of it and especially with what you study about the hazardous side of things and all the reactions that happen.
>
> **Luna**

Guest lectures and industry workshops: inviting industry professionals to deliver guest lectures or conduct workshops can offer students insights into emerging trends, technologies, best practices, and the type of roles and industries engineers work in.

> Bring in industry partners, to host workshops or CPD events or something like that, just to help students get a better idea of what kind of roles are actually sort of day-to-day.
>
> **Theo**

Professional mentorship: mentorship has proven tremendously beneficial for recent graduates, both in terms of skills development and career progression. Nonetheless, during the university degree, mentorship was markedly absent or focused on academic aspects.

> I think back in my bachelor's, they should have promoted internships more, during summer breaks or winter breaks and things like that. It was left to us individuals to go out and hunt for internships and get work experience, but I think my university could have definitely supported the students at that time to at least get some offers or to liaise with some site or companies to help get more people into internships rather than just leaving them out on playing field.
>
> **Ibhanan**

Academic advising and mentorship programmes involving industry partners and alumni should be strengthened to support students in making informed decisions about their trajectories and grow as future professionals. Several graduates emphasised the need to develop relations with professional mentors in their last year of their undergraduate degree or as part of their postgraduate degree. They suggested that universities tap into their alumni network and connect final year undergraduate and postgraduate students with alumni working in industries of their interest.

> At my university, they did run an engineering alumni mentorship scheme, which I have done for about 2 or 3 years. So was after graduating, you can sign up to be a mentor, and it's helping final year students with the plans for after graduating, which has been quite good.
>
> **Noah**

This is especially important for students who are women, who have less exposure to professional mentors. For those graduates, women-focused associations and clubs played an important role in finding a mentor and being exposed to professional opportunities, but these opportunities are not promoted sufficiently as part of their degree.

> Male colleagues do have mentorships, they do have bonding experiences, and they have seniors that help them. I had it harder because I'm a woman.
>
> **Maria**

Promoting active learning

Expanding the use of active learning methodologies supports transition towards more engaging and authentic forms of education, and combats students' perception that learning is too often static and removed from the realities of the engineering workplace. Graduates point to the importance of a wider adoption of real-life projects that bring students from different disciplines into groups. These active learning approaches support the application of complex engineering concepts and theories. By facilitating the engagement with wicked problems, students get to develop a robust skillset that includes problem-solving, teamwork, design, and effective collaboration and communication, all of which are essential for professional engineers.

- **Real-life projects**: graduates emphasise the need for engineering education to include opportunities for students to tackle real-world problems that do not allow for a perfect or predefined solution. These aim to foster creative problem-solving and critical thinking, by considering different types of constraints, success criteria and competing interests.

> At university, it was always about making sure it's completely safe to the letter or the best things possible, but in reality, you're never going to be able to afford the best valve possible, because it's going to have a long lead time when you're in that pressurised situation. What do you do with the options you've got? I suppose group projects really help with the problem-solving aspects, but don't get you to look at the realistic aspects: money, production, safety, that kind of thing. And so, looking more at group projects with a realistic example.
>
> **Amelia**

Collaborative learning: group projects and peer-learning activities can enhance students' teamwork, communication and time management skills, which are crucial in professional settings.

> My university course was quite exam based. And I would say that maybe making it more project-based work would be better. Because one issue that we face at work is just having enough time to do everything, so I think that would help with time management.
> **Fiona**

Case studies: broadening the use of case studies to connect theoretical learning with concrete examples, thereby contextualising academic concepts in practical terms. This method deepens theoretical understanding by illustrating the complexities and nuances of real-world engineering problems, enhancing students' ability to analyse and think critically through these issues. Graduates note that the inclusion of case studies during lectures is especially beneficial when it is followed by classroom discussions. When anchored in real-life scenarios, case studies can compensate for the absence of collaborations with industry for student projects.

> Doing case studies, like taking the real-life scenarios, figure out what we would do, but then having an industry expert coming in to say 'this is what we would actually do,' just for better learning.
> **Luke**

Enhancing exposure to interdisciplinary practice

To prepare students more explicitly for the interdisciplinary nature of modern engineering projects, it will be helpful to move away from a preoccupation with single disciplinary topics or methods. Graduates frequently spoke of the challenge of working in interdisciplinary teams that they encountered as part of their current job, due to not only a perceived difference in thinking and ways of approaching problems but also the lack of familiarity with the concepts and methods of other disciplines. While a major part of their work is interdisciplinary, looking back at their education, graduates consider that they received insufficient to no exposure to interdisciplinarity during their degree.

> Engineering disciplines are not niche, but they are taught in niches.
> **Maria**

To support students to address the complexity of contemporary engineering problems, it will be helpful to offer more opportunities to apply knowledge and methods that span multiple disciplines. The development of such interdisciplinary practices and skills could be achieved by recalibrating engineering curricula in the following ways:

- **Integrated coursework**: incorporating more courses that introduce or blend concepts and methods from varied engineering and non-engineering fields, such as management, policy, ethics or social sciences.

> Having studied biomedical engineering, which was more mechanically focused, when I got into industry, I saw that you can't just know mechanical engineering and then that's the end. You're going to need some sort of software engineering, electrical engineering, you're going to need to know a little bit of these other engineering disciplines as well. If maybe universities and industry are able to, if there's something that can allow engineers to be able to go back just brush up a little bit on the electronics, software or something else.
> **Chamai**

- **Group projects**: these encourage students from different programmes to participate in projects that require collaboration across various fields to prepare them for the multifaceted nature of contemporary engineering challenges. This not only broadens students' disciplinary knowledge base but also prepares them to work effectively in diverse teams and tackle complex, multifaceted problems.

> In my programme we would work in interdisciplinary teams, so different types of engineers. You'd have a problem, and at the end, you would present and you'd have people from different companies there as well. At the time I hated it, but looking back on it I think it was actually really handy because you don't work in silos when you're at work, you don't work with just the people who've got the same knowledge as you. You work with all different types of engineers, and not even just engineers all the time. So actually that was really quite helpful.
> **Anne**

- **Cross-departmental collaboration**: facilitating partnerships between different academic departments can create opportunities for students to engage in interdisciplinary research and learning. This is seen to foster an understanding of what falls under each engineering role and how to develop synergies between different roles.

> For the interdisciplinary engineering, it might have been quite interesting to collaborate with other courses to see how they all interact or even just learn about what inputs you might require from other disciplines, because I don't think I'd ever really given that much thought at uni: what is the electrical engineer doing with a control engineer or how does it interact?
> **Kritika**

Shifting towards more flexible and student-centred degrees

A shift towards flexible and student-centered degree programmes is essential to cater to the diverse interests and career aspirations of students, as well as the development of role- and industry-specific skills. Engineering graduates advocate for educational models that are tailored to individual student profiles and career aspirations. They point to the need for universities to offer a customisable curriculum allowing the pursuit of educational activities according to specific profiles and career goals. This is especially important in the later years of study, after receiving a foundation in technical scientific fundamentals in the first year. Elective courses and personalised learning pathways, including movement between academia and industry, can facilitate this flexibility.

> An element of self-selection at universities, where you select your modules. So in that way it prepares you for making choices. Making sure you're doing things that you're interested in, that are going to help you towards learning what you want. I think that helps you for the workplace.
> **Kritika**

- **Modular curricula and personalised learning paths**: allowing students to choose from a variety of elective courses can enable them to tailor their education to their interests and career goals. Developing systems that support personalised learning journeys, including mentorship programmes and customised course recommendations, can enhance student engagement and success.

- **Extracurricular activities**: currently, extracurricular activities are seen as the bedrock for the development of nontechnical skills and taking ownership of one's own learning. This can take the form of joining student clubs, academic and professional societies such as the Institution of Chemical Engineers (IChemE), taking part in competitions, and attending workshops hosted by the university.

> I think the IChemE does a really good job of paying lunch and learn sharing sessions that are sometimes helpful and generally interesting.
> **Oscar**

- **Alternative and nontraditional pathways**: given the unique profile of each student and the wide range of roles that engineers can work in, graduates recommend against fixed and non-customised educational approaches. They suggest rethinking the linear path of education, with degrees including both study time and immersion in the workplace before graduation, that goes beyond a brief internship.

> It's not one-size-fits-all. You have that traditional route of straight from school to university and then out into industry, but I think having that blend of knowing exactly what you will work on, or the sort of industry you'll go into, depending on obviously the role, and being able to try different things, I think that's another key aspect. To try different jobs, allow students to run many projects and then that way they can choose, taste and see which ones suit them better, what they find more interesting, and they can then explore further. So maybe setting up in the early years of the university.
> **Theo**

New techno-scientific pillars for engineering curricula

Historically, the primary purpose of engineering curricula has been to ensure that all students acquire a solid grounding in essential engineering principles, mathematics, and science. Engineering has nonetheless been subject to change for some time. There has been for some time a growing debate on the skillset needed by the engineering graduate of the future. The core of these developments can be distilled to two main directions. The first is the inclusion of a broader skill set into discipline-specific engineering degrees.

> I think from a technical perspective it does help being experienced to some extent in a particular area of technical information. But I think it can be learned. So it is maybe not quite as important as interpersonal skills.
> **Mandira**

The second, connected, direction is the need for engineers to have an interdisciplinary perspective. This report has been mindful of both developments and, consequentially, has stressed throughout the way in which they could be enhanced, strengthened and extended. Two issues that have been on the horizon have assumed increasing importance and significance and they constitute new pillars to go alongside extent ones. The issues and therefore pillars are:

- **Sustainability and ethical considerations**: given the short- and long-term impact of engineering on people and the environment, it is becoming important to integrate ethics and societal considerations more decisively in the engineering curriculum. Graduates have suggested this goal could be achieved in two ways. First, making courses on sustainable engineering practices, renewable energy technologies, and environmental impact assessments more integral parts of the curriculum. To consolidate this development, it would help if ethical training covered topics such as responsibility, equity and the social implications of engineering solutions. This approach would foster a sense of accountability among future engineers, encouraging them to contribute positively to society and the environment.

> Should be a compulsory module taught by an ethics teacher who has an interest in technology, and hopefully then you can get at least a robust foundation, because nothing is all well and good. Learning the theory at uni, all the practical things, is fine, but the moment you're going into doing this as a job, no matter what you're doing you're making something that is going to affect the world and you need to consider the ethics or the philosophy. The ethics of making that thing, that's not quite simple.
> **Henri**

> Universities could improve on trying to highlight to students the sustainability improvements that could be made to either the technical aspects of what they're learning or how to encourage more sustainability requirements on equipment. That is a very difficult challenge, especially for the technical side.
> **Finnley**

Second, techno-scientific courses could be revised to make room for micro insertions on the societal impact of engineering. Graduates stressed that sociotechnical course components are especially relevant when it comes to introducing sustainability or risk related concepts and assessment tools, such as HAZOP (hazard and operability analysis).

Additionally, graduates recommended that industry representatives were invited as guest lecturers for technical courses, to discuss the ethical dimension of engineering work and practices for ensuring safety.

> We had two lectures on ethics, in the second year. It was something that was interesting, but it felt very much like the university was pushing a check box. I think maybe a bit more time spent on safety stuff that has been relevant to my career could have covered some of that gap, because it is both technical and has deep ethical implications.
> **Oscar**

Teachers with expertise in the ethics and philosophy of engineering and technology provide societal angles to complement technical angles provided by engineering staff and, in doing so, facilitate more imaginative use of educational resources available, such as toolkits developed by the Engineering Council.

> In terms of course content, it would help an IT base, but it's kind of based on Engineering Council, that is to have all information out there on ethical and sustainability examples. So maybe they'd [n.m. teachers] be able to focus on using material that's already out there and trying to promote that a lot more, or maybe dedicate some specific classes for it.
> **Theo**

AI as a working and learning resource into engineering curricula. Clearly, some areas of engineering have been, and continue to be, central to the development of AI. Graduates recognised however that one area of AI, namely machine learning (ML), is being introduced into their companies for two reasons: to assist them to attend to sustainability issues and in response to clients' expectations that they are ML competent. Moreover, graduates speculated about how they would have used generative pretrained transformers (GPTs) if they had been available when they were students. An issue that is now a major preoccupation in higher education in general since students are using GPTs of their own volition.

The challenge for engineering is therefore to recalibrate the curricula to integrate these two new pillars alongside the traditional bedrock of engineering education – a strong emphasis on techno-scientific fundamentals – and more recent interdisciplinary developments. However, graduates countenanced against approaching this challenge in an additive way; in other words, trying to find ways to squeeze more into a pint pot. Instead, they invoked the notion of holism by inviting engineering faculty and/or schools and their departments to identify how to strike a new balance between core scientific principles and engineering fundamentals with broader contextual knowledge, including ethics, sustainability, and societal impacts of technology, and seeing AI as a resource to help them to achieve this goal. Looking to the future, this holistic approach will ensure that engineering curricula retain their commitment to developing deep technical expertise while being mindful of the broader implications of their work as well as enculturating future generations into the responsible use of AI as a working and learning resource. The reports twin call for strengthening links between universities, industry and community partners and more active learning, providing the conditions to achieve this goal.

Emphasising lifelong learning and continuous professional development

The rapid pace of technological advancement and the dynamic nature of engineering projects necessitates a commitment to lifelong learning. To address this issue, it would be helpful if engineering programmes considered the contribution they could make to helping graduates develop a mindset to appreciate the value of continuous professional development and the ability of learning how to learn. One interesting suggestion from graduates was that universities offered mini courses to engineers working in industry to allow them the possibility of returning to study without taking on a full postgraduate degree. The advantage of this type of collaboration between universities and industry is that such microlearning opportunities would be tailored for specific skill profiles and needs.

> On the job learning but small courses: CPD courses and institution events are massively helpful. I think job-specific and micro learning is invaluable.
> **Collin**

Conclusion

While recognising that the UK higher education engineering sector is diverse and no study will ever paint a complete picture, highly noticeable trends emerged from the graduates interviewed regarding their perception of the education they received. The authors acknowledge that significant effort to address these issues is already underway in many institutions. We hope this work will act as a clarion call for redoubled efforts in curriculum reform and renewed support for educational innovation and collaboration with industry and local communities.

Graduate engineers clearly perceived the education they received as too theoretical and removed from the reality of the workplace. The authors recommend that all engineering programmes continue to revise their pedagogic practices to promote active learning approaches, including real-life projects, collaborative learning approaches and the use of industry case studies as central to their education practices. By framing these practices in the context of lifelong learning and continuous professional development, universities would be affirming their curriculum and pedagogic contribution to the formation of engineering expertise.

The adoption of such approaches would be helpfully reinforced through the inclusion of an increased emphasis on the new techno-scientific pillars with the engineering curricula. In particular, graduates highlighted deficiencies in their coverage of issues of sustainability and ethical considerations, noting that the interplay between these issues and the technical content is necessary. Unsurprisingly, the necessity for increased exposure to cutting-edge digital skills, including ML and AI, data analytics and large language models was highlighted. Interestingly, more traditional digital skills were also discussed, with respondents observing they heavily relying on excel in the workplace, something they were not taught in their programmes. It is vital that engineering programmes acknowledge that these are quickly becoming fundamental skills in the engineering (and many other) professions and while rapidly evolving, will need to be as prominent as engineering, mathematics and science in engineering offerings.

It is also recommended that renewed attention is paid to the integration of real-world professional experience within the curriculum and the role of direct collaborations with industry and community partners to support active learning and an exposure to interdisciplinary practices. This will require industry and universities to work together to investigate new models and modes of interaction to strengthen links between universities and industry and/or community partners. This may include internship programmes and work placements, community- and/or industry-sponsored projects and competitions, site visits, guest lectures and industry workshops, and structured professional mentorship during degree programmes. There are already many examples of good practice, but they are yet to be a ubiquitous and highly valued feature of degrees and must become the norm. This will require a whole-sector approach drawing on the convening power of bodies such as the NEPC and Academy, along with the National Centre for Universities and Business and the professional engineering institutions to facilitate sustainable models of large-scale industry and university collaboration.

While industry/university interaction was seen as critical, there was also a recommendation to increase and enhance students' exposure to interdisciplinary practice within curriculum, citing a perception of engineering as siloed within disciplines. It was observed that current discipline-based degree programmes do not reflect practice and that students would benefit from increased opportunities to work with other disciplines through group projects based on cross-departmental collaboration. In addition, graduates recommended more opportunity to create personalised learning paths as well as increased support for alternative and nontraditional pathways through the education system.

Implementing these recommendations will have a transformative effect for engineering education, ensuring that it remains relevant, dynamic, and responsive to the needs of both industry and society. By strengthening university–industry links, promoting active and interdisciplinary learning, offering flexible and student-centered degrees, focusing on techno-scientific fundamentals, integrating sustainability and ethics, and emphasising lifelong learning, we can prepare engineers to excel in an increasingly complex and interconnected world. These changes will not only benefit students but also contribute to the broader goal of engineering a sustainable and equitable future.

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Appendix 1: **interview methodology**

Participant selection

Participants for the interviews and focus groups were identified by a Linkedin campaign and through contacts with a number of professional associates. The focus groups, interviews and pre-survey instrument were approved by the UCL Ethics Committee under project code UCL Research Ethics Committee Approval ID Number 14949/002. It was logged with the UCL Data Protection Officer as required by data privacy legislation (GDPR and DPA 2018) with UCL as the controller of the data. The lawful basis for the processing of personal data is – performance of a task in the public interest. All participants were informed of their rights and agreed to participation. Once chosen each participant received a pseudonym and none is identified in the study by their name.

Ahead of the focus groups / interviews participants were asked to complete a short survey. This survey as administered using the Qualtrics survey platform. The survey collected the follow information:

- Name
- Title of first degree, university and year of graduation
- Title of any subsequent qualification, provider and year of award
- Current employer:
  - name
  - date of employment
  - title of work role and main responsibilities
  - perceptions of current position.
- Previous employer(s):
  - name
  - date of employment
  - title of work role and main responsibilities
  - perceptions of previous position.

Participant overview

Sample characteristics

There were 40 participants in total: 14 women and 25 men.

They had attended 15 different UK higher education institutions, and one was educated entirely outside the UK – although there is no data on five participants. With a single exception all had graduated.

Seventeen participants had studied chemical engineering; three civil; six electrical/ electronic; five mechanical; the remaining eight various allied subjects: aeronautical engineering; two studied computer science; engineering design; two studied medical engineering; physics; and systems engineering. One did not provide details of their educational background.

Format

During the focus groups and interviews, CEE facilitators led discussion in small- to medium-sized groups around three key clusters of questions. These three clusters of questions are designed on Eraut's 'elicitation' principle, that is, start with the present, delve into the past and, having asked people to reflect contemporaneously on their current concerns and preoccupations and retrospectively on prior concerns and preoccupations, to ascertain whether they converge or diverge. We then asked them to speculate prospectively on what they think might be ahead of them. The focus groups and interviews explored in a dialogic manner the skills used by recent graduates to handle the responsibilities of their current role as well as during their study to work transition, and how their study programmes equipped them with the relevant skills that are key for their profession. Additionally, the study identified the recent graduates' views of how university could have prepared them better for acquiring the skills they deem essential for their current roles, and the skills they consider they need to address future societal challenges and recent technological developments.

The outline of the focus groups is as follows.

Setting the scene (a rough sketch)
Welcome and explanation of the purpose of the event and the pattern of activity that everyone will engage in.

Introductions and icebreaker
Name, role, employer, length of employment, why did you agree to attend this event.

Cluster 1. Thinking about your current role
What has been the most interesting/challenging experience that you have had?

How did this come about: part of your work role, you volunteered to take on this experience, it just cropped up unexpectedly as part of your work role etc.?

How far, if at all, do you think your university first (or subsequent) degree:

- Prepared you for this/these experiences?

  Prompts – can you be specific which knowledge, skill etc. in what ways, and how exactly it helped?
- To what extent do you feel your university experience was unhelpful in preparing you for this/these experiences?
- Could your university or yourself have done anything additional to prepare you for this/these experiences?

  Prompt – personal/discipline-based networking – may refer to the 16 skills if necessary.

Cluster 2. Thinking about your previous role
What was the most interesting/challenging experience that you have had?

How did this come about? Part of your work role, you volunteered to take on this experience, it just cropped up unexpectedly as part of your work role?

How far, if at all, do you think your university first degree assisted your transition to employment to engage with you this/these types of experience?

Prompts – can you be specific which knowledge, skill etc. in what ways, and how exactly have they helped? How far, if at all, do you think your university first (or subsequent) degree:

How far, if at all, do you think that your employer assisted your transition to employment to engage with you this/these types of experience?

Prompts – can you be specific about training, mentoring, work and task rotation and how exactly they helped?

To what extent do you feel your university experience was unhelpful in preparing you for this/these experiences?

Prompts – can you be specific about why?

Could your university or yourself have done anything additional to prepare you for this/these experiences?

Cluster 3. Thinking about your future as a practicing engineer
Looking, say, five years ahead, what do you feel are the greatest challenges that you will be facing as a practicing engineer?

Prompts – ChatGPT and other forms of machine learning, policies for sustainability etc?

To what extent, if any, do you feel that your employer is trying to support you to address that/those challenges?

Prompt – can you be specific in what ways are they doing so?

To what extent do you feel that the engineering (or other) degree that you studied prepare you in any way to face those future challenges?

The engineering (or other) degree that you studied would need to change to support future generation of practicing engineers?

Prompt – can you be specific in what ways will they need to do so – reduce content/add new content/develop new pedagogic approaches/ devise new modes of assessment?

Finally – do you have any further thoughts on who else could support you as a practicing engineer?

Prompt – yourself via networking, professional associations.

> The study identified the recent graduates' views of how university could have prepared them better for acquiring the skills they deem essential for their current roles, and the skills they consider they need to address future societal challenges and recent technological developments

Appendix 2: **curriculum survey methodology**

To examine the planned curriculum, a desk review was based on publicly available documents, as published on the website of each education provider. This desk-based study considers a subset of the 30 largest education providers (the largest 30 cover around 60% of engineering graduates) selected on the quality of detail contained in their published curriculum information. The examination was concerned with identifying nontechnical skills students would be expected to acquire on completion of modules.

Methodology

Sixteen distinct UK higher education institutions were selected. This exercise provides some coverage of Russell Group, Pre-92 (non-Russell) and Post-92, although it should be noted that the publicly available curricula tends to be more readily available in Russell Group and Pre-92 universities.

In the case of each institution the programme and module course detail documents were sourced for four key engineering disciplines: chemical; civil; electronic/electrical; and mechanical. Higher education institutions' programme specifications offer a detailed guide to the content of each module comprising degree courses. The public availability of these documents dictated to some extent the final sample of sixteen.

Each document, principally relating to MEng degree courses for the academic year 2023/24, was examined for details of the programme / modules that featured reference to any of 15 key non-technical skills: communication; digital; ethics; independent working; interdisciplinary working; knowledge development; leadership; legal; policy; problem-solving; risk management; site visit(s); sustainability; team/ group work; work ethic.

The occurrence of terms relating to each of the 15 skills, such as "communication", was examined across each document, and in each case its occurrence recorded if it appeared as a reference to a skill that was specifically taught within a given module or programme.

The final outcome was a frequency table covering all 16 institutions across all four disciplines for all 15 skills, from which inferences about the provision of the non-technical skills in engineering courses was made, and their relative significance in terms of their prevalence.


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