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Emerging Trends, Approaches And Challenges In Engineering Education In The UK

Stella FOWLER
Engineering Professors' Council, United Kingdom; UCL Centre for Engineering Education, s.fowler@epc.ac.uk

Ines DIREITO
UCL Centre for Engineering Education, i.direito@ucl.ac.uk

Kate BELLINGHAM
UCL Centre for Engineering Education, kate.bellingham.20@ucl.ac.uk

See next page for additional authors

EMERGING TRENDS, APPROACHES AND CHALLENGES IN ENGINEERING EDUCATION IN THE UK (RESEARCH)

S Fowler [1]
Engineering Professors' Council, London UK
and
Centre for Engineering Education, University College London
UK
https://orcid.org/0009-0007-5319-6931

I Direito
Centre for Engineering Education, University College London,
UK
https://orcid.org/0000-0001-8102-831X

K Bellingham
Centre for Engineering Education, University College London,
UK
https://orcid.org/0009-0003-1278-2767

J.E Mitchell
Centre for Engineering Education, University College London,
UK
https://orcid.org/0000-0002-0710-5580

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ABSTRACT

Worldwide, engineering educators are searching for approaches, pedagogies and change strategies to develop programmes that will equip their graduates to be successful engineers, effective engineering leaders and catalysts for social

[1] *S. Fowler, s.fowler@epc.ac.uk*

development. In the UK, focus largely rests on new pathway initiatives and new Higher Education (HE) institutions. There is little shared understanding of the established sector's evolution from a maths and science heavy curricula to the innovative and world-leading models of engineering education found in the UK HE sector today.

This research paper looks at examples of trends that are emerging in engineering education provision in the UK and highlights case-studies of innovative provision and new models in the sector. A mixed-mode approach of desk research, structured survey and case studies were used to collect data. Data analyses show that across the UK there is a complete spectrum of engineering higher education, with the reality of the provision being complex with a broad diversity of educational models on offer. The research reviews current teaching and learning approaches and highlights evidence of innovations in laboratory practical teaching; use of projects; dissertation projects; project-based learning, project-based initiatives and frameworks; and examples of new buildings driving curriculum innovation.

In particular, the paper presents and discusses data concerning current teaching and learning approaches (including barriers and impact of the coronavirus on learning approaches and provision of engineering education in the UK), information on innovative elements, and COVID mitigation and engagement with new methods of delivery.

1 INTRODUCTION

Engineering education has been responding to call from industry, from students and from professional bodies for change to ensure graduates are ready for the work environment and prepared to face the global challenges of the 21st century. This has led educators to implement change strategies to develop programmes that will equip their graduates to be the successful engineers, effective engineering leaders and catalysts for social development. In the UK there have been government-led initiatives (for example degree apprenticeships), entirely new institutions (for example, NMITE (New Model in Technology and Engineering), TEDI London (The Engineering Design Institute London) and Dyson Institute) as well as evolutions of established programmes or new programmes in established institutions. These developments have all been established in the context of a shifting landscape of student funding, including a growth in international student numbers and falling (when adjusted for inflation) funding for UK students just as the numbers of UK 18-year-olds is starting to increase.

In this paper we aim to paint a picture of the UK Engineering Education sector and look at the prevalence of key approaches to teaching and learning to better understand how the sector is evolving. We will present the results of a survey of engineering education leaders in higher education institutions across the UK supplemented with public data-sets. We show that the professional development of engineers at this higher level is not a single track although certain trends and approaches emerge as being dominant approaches.

2 METHODOLOGY

This work takes a mixed-mode approach of desk research, structured survey and case studies development to collect data. The survey data reported in this section is

drawn from an online survey of Engineering Departments undertaken between June and early September 2022. Two versions of the survey were administered, one targeted at faculty level strategic leaders (Deans/Vice-Deans or Associate Deans Education) and one at the Department/Disciplinary Level. The first survey link was sent to all Deans of School/Faculties which contain an engineering activity and where they could be identified all Vice-Deans Education, Associate Deans Education or Directors of Education. The second survey was sent to all Heads of Department and where possible departmental teaching leads. Data is drawn from the Higher Education Statistics Agency (HESA) Staff and Student data-sets. The HESA student data includes the Common Aggregation Hierarchy (CAH) 10-1 group codes which covered Engineering subjects (but not computing or materials science) and uses student Full Person Equivalent (FPE) as recorded by HESA. it considers first degree (including Foundation year) including bachelor's degrees (BEng) and integrated masters (MEng) and includes programmes in England, Scotland, Wales and Northern Ireland.

3 RESULTS

3.1 Engineering education provision in the UK

Desk research illustrated that across the UK there is a complete spectrum of engineering higher education, with the reality of the provision being complex with a broad diversity of educational models on offer.

- 109 UK universities offer undergraduate engineering degrees (not including software engineering)
- All UK universities teaching engineering offer either BEng (Framework for Higher Education Qualifications (FHEQ) Level 6) – including a few only offering BEng top-up – *or* Integrated MEng (Level 7) courses.
- Most UK universities teaching engineering offer *both* BEng (FHEQ Level 6) *and* Integrated MEng (Level 7) courses.
- Most UK universities offer one-year postgraduate taught masters' courses.
- Four UK universities only teaching engineering at postgraduate level (Level 7) – although only one at scale.
- Nearly three quarters (72%) of UK universities are advertising at least one foundation year option (in some cases, a university's foundation year will be taught at a local Further Education (FE) college). Note that degree programmes in Scotland are typically a year longer, so the foundation year model is not evident.
- Nearly one quarter (23%) of UK universities offer an Higher National Certificate (HNC) (level 4), Higher National Diploma (HND) or Foundation Degree (level 5).
- Several UK universities offer a 'top-up' year to complete a BEng degree, even where they do not offer level 4 or 5 qualifications.
- Nearly a third of the universities offer part-time study of undergraduate engineering (32%) but this is typically as part of a degree apprenticeship, top-up degree or at universities offering non-degree level courses.

- Nearly one quarter of universities offer the opportunity of a year-long industry placement or the chance to study abroad for a year.
- Although a large number of universities are involved in the delivery of engineering degree apprenticeship, the majority deliver only one or two standards in engineering with only 9 delivering more than three.

Alongside traditional titles such as mechanical, civil, electronics or chemical, undergraduate students can enrol at undergraduate level for courses including: Motorsport Engineering; Energy and Sustainability Engineering; Civil and Geo-environmental Engineering; Coastal and Flood Engineering; Offshore, Subsea and Pipeline Engineering; Structural and Fire Safety Engineering; Yacht Design and Production; Aeronautics and Astronautics with Engineering Management; Electronic Engineering and the Internet of Things; Robotics and Embedded Systems Engineering; Biomaterials and Tissue Engineering; Design, Innovation and Creative Engineering; Ordnance, Munitions and Explosives.

The opportunities for postgraduate study are even more varied and specialised with frequent interdisciplinary links e.g., with computer science and technology, medicine, architecture, management, and the full range of physical and biological sciences. Expertise in the engineering departments of our world-renowned universities demonstrates the global recognition of engineering in the UK HE-sector. Meanwhile, regional context or links with local industry frequently allow individual universities their own engineering specialisms reflecting the transformative role of the Higher Education institutions in their own individual setting.

3.2 Scale of engineering education provision in the UK

The data shows that the total number of students (FPE) studying engineering at first-degree or on a postgraduate course in the academic year 2020/21 is 149,725. It shows that 79.8% are studying at English HE institutions, with 12.3% in Scottish, 5.5% in Welsh, and 2.5% in Northern Irish HE institutions. If considered by region it can be seen there is a strong presence of engineering schools and engineering students right across the UK.

When we rank the size of individual providers, we see that there is considerable variation in the scale and make up of institutions. The largest institution in the UK is the Open University which offers flexible distance and open learning part-time study, predominantly for UK at undergraduate level. On the left-hand side of Fig. 1, we see a small number of very large providers with 4,000-5,000 students, around 20% at postgraduate taught level. There institutions will typically offer a wide range of engineering disciplines almost always including, Electrical engineering, Mechanical engineering, Civil engineering and Chemical engineering. We then see a wide range of institutions with between 1,000-3,000 students. Here there is more diversity in disciplines offered, with some also offering general engineering entry routes with specialisation later in the degree. The majority will offer Electrical engineering, Mechanical engineering and Civil engineering. Finally, around half of the institutions that return data relating to engineering subjects have total cohorts of less than 1,000

students, often offering a more specialised range of engineering subjects and typically part of broader science and engineering faculties. Although over 100 institutions are represented here, the largest 30 admit over 60% of the total engineering student body.

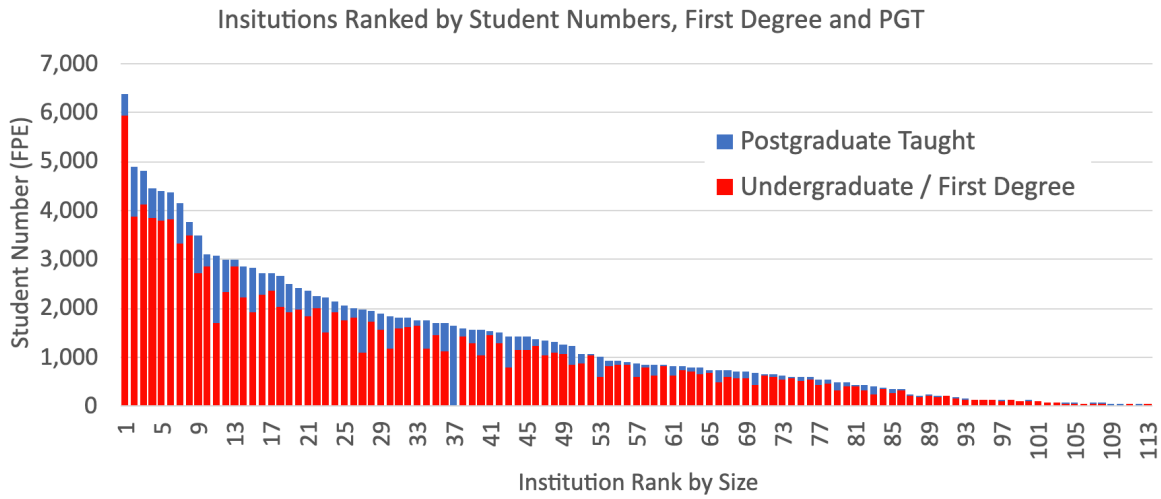

Fig. 1. Size by Student Number of UK HE Engineering Providers, First Degree and Postgraduate Taught (PGT). Source: HESA Student Record 2020/21

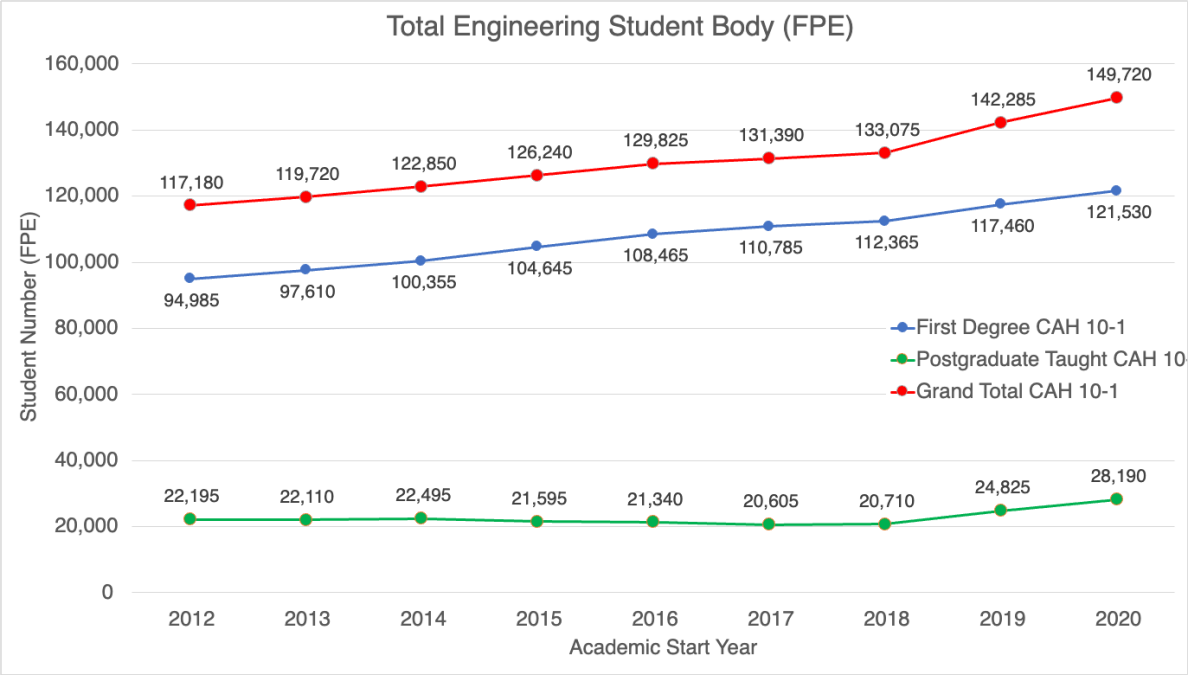

Fig. 2. Trends in UK Engineering Student Numbers 2012/13 and 2020/21. Source: HESA Student Record 2012/13 to 2020/21

3.3 Trends in engineering education provision in the UK

In 2020/21 engineering students made up around 5.5% of the total student population in the UK having risen from 5% over the decade from 2011/12. The majority of this growth is at first degree level – rising from 5.3% of the total student population in 2011/12 to 6.1% in 2020/21, against a fall in Postgraduate taught numbers which have fallen from 4.1% to 3.8% in the same period.

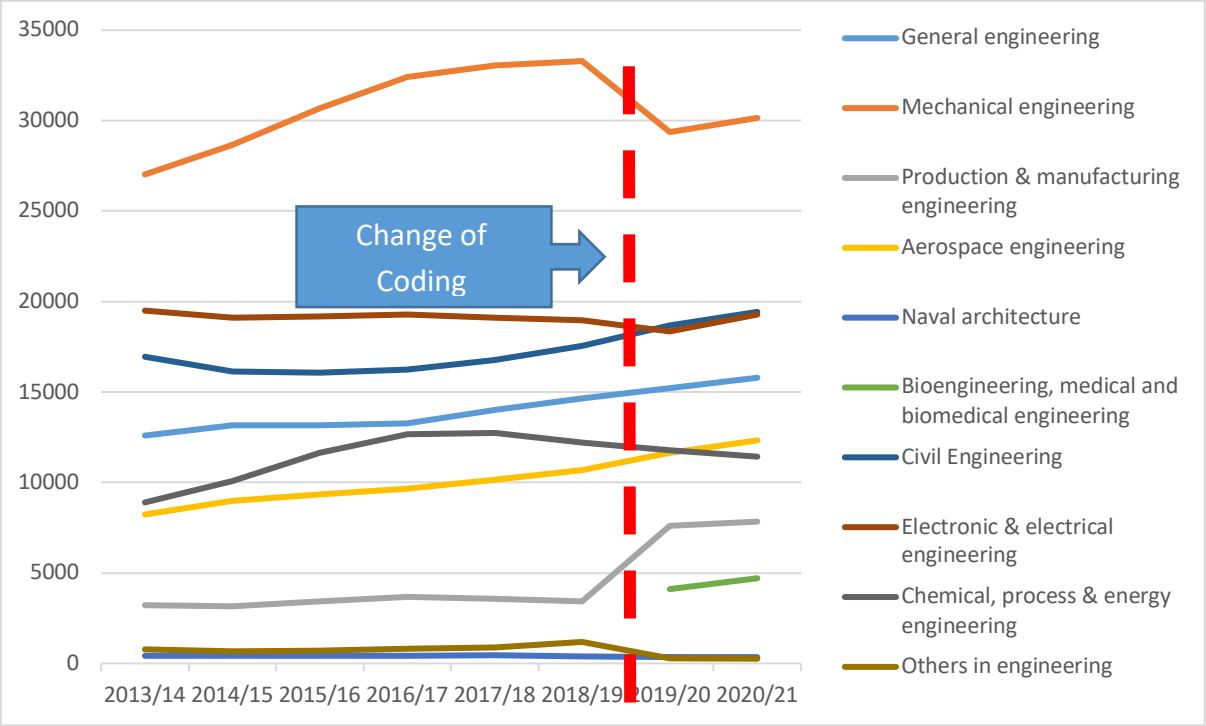

Fig. 3. Trends in UK Undergraduate Engineering Student Numbers 2012/13 and 2020/21. Source: HESA Student Record 2012/13 to 2020/21

If we look at specific disciplines, as shown in Fig. 3, we see that undergraduate level Mechanical engineering remains the most populus discipline. Although Electronic and electrical engineering is taught in slightly more institutions (81 institutions reported more than 50 students compared to 77 for Mechanical engineering) there are more large Mechanical engineering departments with 28 reporting more than 500 students (compared to just 12 for Electronic and electrical engineering). We should note that in Fig. 3 for first degree and Fig. 4 for postgraduate taught programmes that the coding scheme used to record disciplines changes between the 2018/19 and 2019/20 academic sessions. Therefore, the sudden jumps in certain disciplines, and the appearance of Bioengineering, medical and biomedical engineering as a discipline are likely to be predominantly due to this coding change rather than any change in the student body. Despite this, at postgraduate taught we do see some significant shifts in some disciplines, most notably the rise in Electronic and electrical engineering and Production and manufacturing engineering.

3.4 Current teaching and learning approaches

Competition amongst providers, developments in learning technology, initiatives from government and pressures for industry and regulators have led to significant developments in the approaches to engineering education in the UK over the last decade. Despite this there is still a conception that all engineering education at university level can be characterised is being heavy in maths and sciences, with applications only developing in later years. This is in line with what David Goldberg in the US (Goldberg and Sommerville 2014), characterised as the maths/science death march of engineering education. While it is undoubted true that this has been

the case, our research has shown that within the majority of institutions there are developments towards more student-centred and active-learning approaches that have been advocated for by thought leaders in engineering education for some time. Our review shows a complex picture across the UK with spectrum educational models on offer. In this section of the report, we will look at examples of trends that are emerging in engineering education provision in the UK and highlight case-studies of innovative provision and new models in the sector. We highlight evidence of laboratory practical teaching; use of projects; dissertation projects; project-based learning, project-based initiatives and frameworks; and examples of new buildings driving curriculum innovation. This falls very much inline with the directions of travel identified in the 2018 MIT report, Global State of the Art in Engineering Education (Graham 2018) which places the programmes delivered in the UK in a global context.

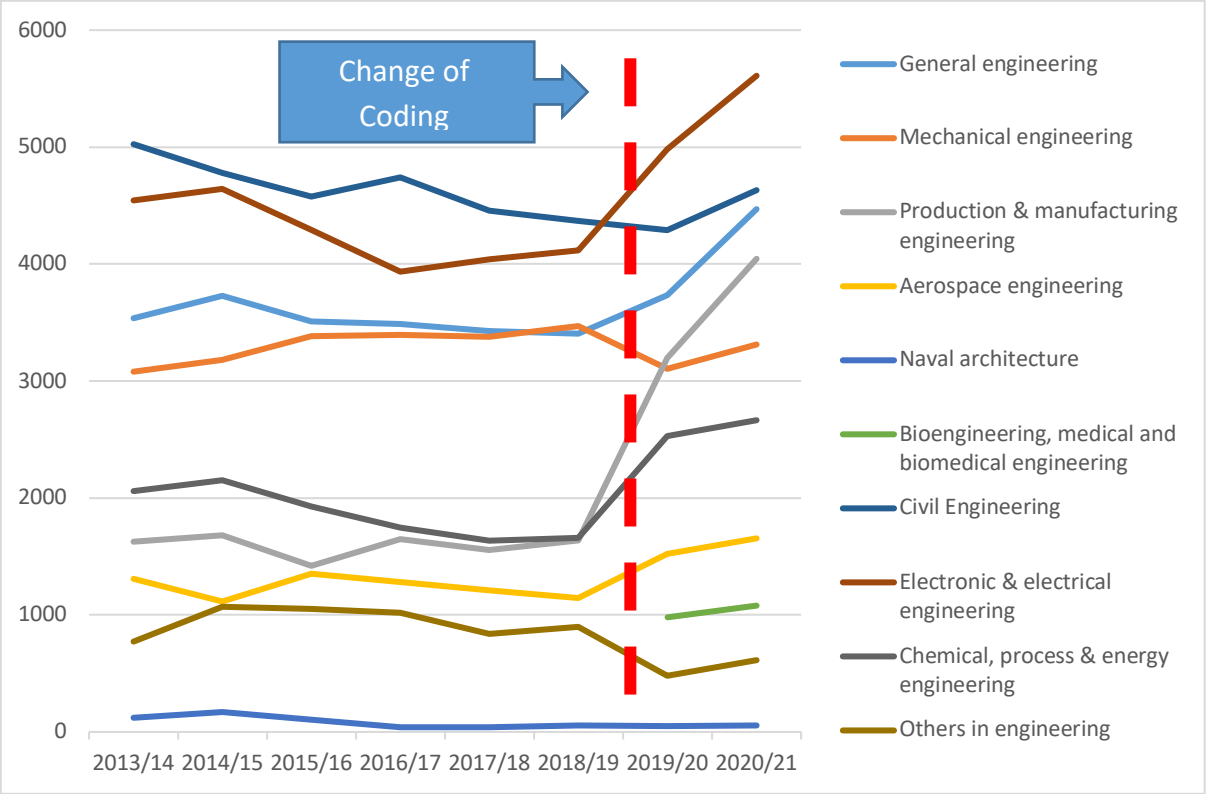

Fig. 4. Trends in UK Postgraduate Engineering Student Numbers 2012/13 and 2020/21. Source: HESA Student Record 2012/13 to 2020/21

3.4.1 Active learning

As part of the survey, engineering department leaders were asked the proportion of courses/modules that implement active learning as the dominant form of teaching. For most respondents, active learning is reported as the dominant form of teaching in 25% to 75% of the courses/modules taught at UG level. Overall, active learning is implemented at a higher proportion of courses in UG in comparison to PGT level. However, the proportion of teamwork activities in engineering programmes is

lower. It varies between 25 and 50% for most UG programmes and less than 25% for most PGT programmes represented in the survey.

The analysis of participants' responses to the question "Can you give an example of active learning at your department that works particularly well, and why?" suggested that what 'worked well' was associated with the following student outcomes: skills development and deeper understanding; workplace-related projects and skills; thinking beyond their discipline; higher enthusiasm and creativity. Examples of active learning activities included: group work and/or teamwork, competitions, interdisciplinary projects (including design, build and test), work-based learning and fieldwork, entrepreneurship challenges and courses, and flipped classrooms.

3.4.2 Practical teaching

Engineering is commonly viewed as a practical discipline. As we have seen above, active learning and projects are key element of the modern engineering education experience. In the survey, we asked departments, what types of hands-on/practical learning approaches are used in their engineering programmes, and to provide examples of the most relevant approaches. All engineering programmes represented in the survey use hands-on/practical learning approaches, in both UG and PGT programmes, and across all years. The most relevant approaches are predominantly 'projects', including research and design projects (including digital design), in teams or individually. Other frequently mentioned approaches used to develop experimental practical skills included 'laboratories', 'workshops' and 'makerspaces'. 'Experiments' included laboratory work or classes, as well as home experiment kits or remote experiments. Other approaches mentioned included 'testing' (e.g. mechanical, circuit design and test, materials testing), 'computer-aided design', 'fieldwork' or observations (e.g. land surveying and site visits).

3.4.3 Barriers and impact of the coronavirus on learning approaches and provision of engineering education in the UK and COVID mitigation and engagement with new methods of delivery

The survey looked into how engineering schools approached teaching and learning as a response to covid-19 pandemic. As expected, practical activities were substantially reduced, with virtual labs and take-home kits taking a significant increase. Provision was put in place to allow students to be able to download specialized software onto their own machines. Other activities included labs with adequate measures (such as physical distancing) and small group activities on campus. Considering the upcoming academic year (2022/23), engineering schools were asked to rate a set of statements using a scale ranging from 1 (extremely unlikely) to 5 (extremely likely). Respondents were more likely to change provision in order to include more use of online simulation tools (M=3.83), use of blended/hybrid modes of instruction (M=3.76) and use on pre-recorded lectures (M=3.55) than in pre-pandemic times. They were less likely to use virtual placements (M=1.83) and take-home kits (M=2.26). There were more likely to use blended/hybrid modes of instruction, use of online simulation tools, pre-recorded lectures. Despite some

success and some advantages being observed, there were less likely to use virtual placements, take-home kits, as well as live online lectures.

3.5 Innovation case study

A common feature of the majority of developments reported is the renewed emphasis on project-based and practical teaching. This demonstrates a significant allocation of staff time and in some cases significant investment in new laboratories. For examples, the Department of Multidisciplinary Engineering Education based in the new Diamond Building at the University of Sheffield have used these cross-faculty facilities to pioneer an approach to offering practical teaching based on innovative practical laboratory sessions at scale to departments across the faculty (Garrard, Bangert and Beck 2020). Recently the School of Engineering at the University of Birmingham has introduced Integrated Design Projects (Cooke et al. 2018) as part of a common first year of study before specialisation in a discipline. Through the Integrated Engineering Programme (IEP) UCL has introduced a 'thread' of project-based learning experiences throughout the first two-years of the programmes (Mitchell et al. 2021). A number of institutions reported implementing CDIO (Edström and Kolmos 2014) as a framework to increase the number of project activities within their programmes. Examples include Aston University (Thomson and Clark 2018). Queen's University Belfast (Hermon and Cunningham 2011) and most recently Canterbury Christchurch University. Another initiative that is starting to gain momentum is Vertically Integrated Project (VIP) with examples at the Universities of Strathclyde (Strachan et al. 2019) and St Andrews (Coyle et al. 2021).

4 SUMMARY

Our review of the engineering higher education sector within the UK shows that student numbers and the popularity of engineering as a discipline continues to grow in a sector that has a diverse range of offerings and that is, perhaps more slowly than some would like, embracing new teaching methods included the development of practical and project based teaching throughout the curriculum.

5 ACKNOWLEDGMENTS

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