

New approaches to engineering higher education in practice







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Introduction



The engineering sector currently faces a skills shortage. The supply of work-ready engineers lags behind demand and employers regularly highlight gaps in the skills of the graduate engineers coming into workforce. At the same time, the aspirations and career paths of students are changing. The new generation of potential engineers want to study and work in different ways.

In order to address these challenges, the Institution of Engineering and Technology (IET) and the Engineering Professors Council (EPC) formed the New Approaches to Engineering Higher Education programme. Its task is to examine how a sector-wide shake-up of engineering teaching in higher education could make a difference.

Following on from our conference in 2017, we published our 'Platform for Change'. This outlined the six action areas to address across engineering higher education in order to create the engineering skills pipeline that industry needs.

Through efforts to increase diversity, a greater emphasis on creativity and better partnership working with industry to prepare graduates for the workplace, universities are already making progress.

At this year's conference we are showcasing examples of best practice which are making a difference to the six action areas. These universities have pioneered changes that make their engineering courses more innovative and focused on the future needs of the engineering sector. This document provides an in-depth overview of the changes made and how they were conceived and delivered.

By sharing the journeys of those who are already making a positive difference, as well as the lessons learnt along the way, we hope to inspire other institutions to come up with new approaches of their own.

▬ A platform for change

The IET and the EPC wants those who are in a position to lead an evolution in engineering education to reshape the way students learn. We believe engineering higher education should be developed in these six ways:

Incorporating creativity into engineering – To reflect developing industrial needs and to attract a broad range of applicants, engineering programmes should enhance and emphasise the creative and innovative nature of the work of engineers. Although maths and science are important, they are a necessary, but not sufficient, part of the skill set required.

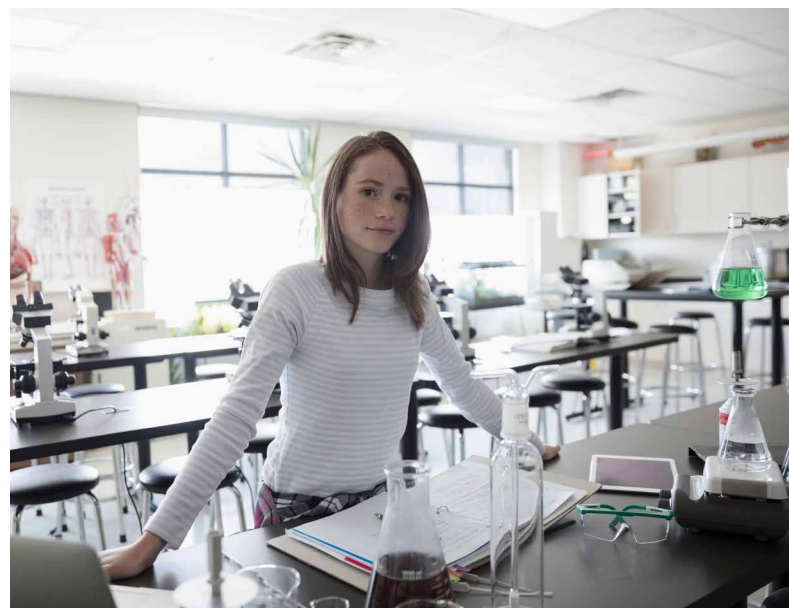
Broaden the diversity of students – The image of engineering means that women and ethnic minorities are far less likely to apply to study it. The emphasis in schools of maths and physics as a requirement to study engineering at top engineering schools also restricts access to the subject. This is especially true in physics where the proportion of female students at A-level is particularly low. Opportunities to increase the diversity of engineering students should be explored.

A strong emphasis on project work – Students are enthused by authentic and relevant engineering experiences. In engineering, a primary vehicle for this is the design project. It's not enough just to do these in the latter years, once sufficient grounding in theory is achieved. To develop skills and encourage active learning, project work should happen from day one and spread throughout the degree programme.

Industry engagement in design and delivery – Working with industry to understand the skills they need in graduates is vital. It will help create an effective workforce for the future, ensuring that students graduate with up to date and relevant skill sets. This is particularly important to encourage students to enhance their transferable and employability skills.

Experience of the workplace for students – The formation of the professional engineer is a process which involves education, training and experience. In an ideal world these are not separated. Academics and industry must work together to develop programmes which bridge the gap between university and work. This must be done in a way that provides equal opportunities for all students, regardless of background and career aspirations.

Greater interdisciplinarity – Modern engineering challenges and the global issues that most enthuse our current cohort of students require the knowledge of many disciplines. The solutions will come from engineers across the disciplines and non-engineers putting the right expertise to work. We must prepare our students for this by getting them to undertake complex projects in interdisciplinary teams.



Industry engagement

Edinburgh Napier University Institute for Sustainable Construction

Programme
Built Environment Exchange (beX).

New Approach
beX is an award-winning Scottish Funding Council university-industry partnership which develops future skills and talent to increase productivity and modernise the construction sector practise.



About the programme

beX creates opportunities for students, employers and stakeholders to design and collaborate on innovative projects, supervised by research leaders, with access to international partnerships and best practice.

beX provides a pipeline of future talent for industry and academic partners. Its goal is to accelerate change in construction culture towards more progressive forms of delivering the built environment.

Penultimate and final year students apply to participate in the programme. The application is open to all disciplines but is primarily for those on construction and built environment-related degree courses.

The selected beX cohort is provided with additional learning content geared towards entrepreneurship in the built environment with a particular emphasis on developing more holistic knowledge sets considering whole life cycle value.

The cohort have more direct access to opportunities available via various channels including innovation internships, master scholarships and employability on live research and commercial contracts.

Overview of the new approach

beX develops the champions of change who will modernise and transform the construction sector, embedding them into the industry.

It delivers high-level skills development for modern construction, by identifying and nurturing future talent for the industry from current graduates and employee. It gives them the technical skills and business confidence to drive change.

Although beX primarily targets students in architecture, engineering and construction, it is not restricted to these sectors as it is essentially about delivering a more sustainable built environment. This can require other skills in for example computing & IT for digitisation or arts and creative industries for design thinking.

The opportunities created include:

- Innovation Internships - partnering with Entrepreneurial Scotland Saltire Scholarship
- Master Scholarships - partnering with the Construction Scotland Innovation Centre
- Employability through the Research and Commercial Contracts of the Institute of Sustainable Construction.

beX also provides augmented learning through commercial, leadership and entrepreneurship training. For the last two years beX has partnered with industry and stakeholders to deliver a

learning week in collaboration with Harvard Graduate School of Design. The learning week focused on offsite and industrialised timber construction through factory tours, site visit, seminars and workshops including a mutual placemaking exercise (design thinking for the built environment) to address the challenge of vacant derelict land.

The findings of the week and wider collaboration between Edinburgh Napier University beX and Harvard Graduate School of Design have exhibited at Architecture and Design Scotland in Glasgow and in Boston, USA at the Industrialised Wood Building Construction Convention.

How the programme relates to other New Approaches facets

beX is aligned to the other New Approaches facets by:

- Pioneering Design Thinking for the Built Environment via Metal Placemaking exercises.
- Encouraging students from all backgrounds to consider the programme – resulting in a 22% female uptake.
- Encouraging teamwork through additional development focused on leadership, team building and entrepreneurship.
- Focusing on employer engagement – the programme has won a Scottish Funding Council "Outstanding employer engagement in universities" award.

- Supporting high impact research – including research and technical test work on a tulipwood Cross Laminated Timber (CLT) exhibition at the V&A in London called Multi-Ply. A further collaboration project with beX scholars supported the structural design and test work of volumetric CLT units for the Dyson Institute for Technology working with Carbon Dynamic.
- Collaborative learning – collaborating with Harvard Graduate School of Design to complete two collaborative learning weeks focused on learning about offsite construction and the timber supply chain in Scotland.

Leading and managing the change

In 2015 the university leadership team sponsored a strategy project to evaluate the operational success of the Centre for Offsite Construction + Innovative Structures (COCIS) in order to create model of operation which is scalable and transferable to other departments.

The project identified how COCIS was successfully underpinning industry led research and innovation with student talent and thus building capacity and creating opportunities. The key transferable components identified were internship, scholarship and employability. This resulted in the creation of a business plan for sustainable growth and the identification of strategic partners.

COCIS had a pipeline of funded projects, established university partners undertaking similar operations in their own contexts and a network of industry partners willing to engage. Therefore, in the spirit of innovation and entrepreneurship beX was piloted with seed funding of around £20,000 in the 2016/7 academic year. This resulted in a successful exhibition at the Vision event for architects, specifiers, clients and suppliers in London.

beX publicly launched on the 14th of November 2017 at Code Base, a business incubator in Edinburgh. At the point of launch, £110,000 had been raised for master and international scholarship support with beX scholars being actively involved in over £362,000 of research and innovation funding.

Building on this success, in 2019 beX scholars have now helped attract over £550,000 of research and commercial income and more than £225,000 has been secured for Innovation Internships and Master Scholarships.

Benefits of the new approach

beX has resulted in students, colleagues and external partners co-evolving a Built Environment Community and Built Environment pathway for upskilling with connectivity to Schools via Design Engineer and Construct.

The new approach inspires more individuals to consider construction as a career and provides alternative options for upskilling a graduate apprenticeship.

BeX accelerates careers, encourages diversification - 22% of beX Scholars are female compared to a construction sector average of an 11% - and enables international research, work and study.

Over the last two years beX and Harvard Graduate School of Design have collaborated on an international learning week in the context of Scotland with students working together to find a solution to the UK's housing crisis. Harvard associate professor and practicing architect George L Legendre said:

"This week of workshops, lectures and factory visits reflects our shared belief in the importance of off-site manufacturing, and the potential value of a collaboration between architects and engineers."

Individual success stories include ones such as Rory Doak, who did an international internship with Class Rooms for Malawi and via an employability contract provided structural engineering support for the Dyson Institute of Technology.

Making the changes: learning points

beX is an entrepreneurial approach to shaping the delivery of the built environment and is creating meaningful impact by investing in future talent.

It has been formed as a start-up through endeavour and collaboration and is accelerating the careers of the individuals that engage with it. The approach taken was therefore to make it happen by showing leadership and commitment, understanding industry need and taking an approach that maximise student value. By combing these different facets and merging them together value return to each stakeholder was determine and maximum impact demonstrated.

The strong advice is therefore to understand from each partner what creates value and try to maximise this via collaboration.

It is important not be frightened of failure: failing fast is better than not trying, failing fast also determines what works.

beX has been a steep learning curve and making it work within a university system not without its challenges.

However, if something has the correct trajectory people are supportive and momentum will build to the point where the concept will stimulate change and evolve new approaches.

Be sure along the road to collect qualitative and quantitative evidence of the programme's impact.

Student feedback

"One of the best experiences as a beX scholar was the opportunity to be involved with the manufacturing process of Tulipwood CLT for the American Hardwood Export Council Multi-Ply project. I learned first-hand how CLT is made at the Construction Scotland Innovation Centre and how supply chains are created, this really expanded my knowledge of the sector. This increased my awareness about the dynamics behind the delivery of a project and helped me take more informed decisions for my future. I'm certainly committed to more sustainable forms of construction."
Carola Calcagno

Statistics

- beX publicly launched on the in November 2017 Number of students
- So far 41 students have participated in the programme
- The female-to-male student ratio is 22%-78%.

Interdisciplinarity

University of Warwick School of Engineering

Programme

School of Engineering Undergraduate Engineering Degrees:
A Curriculum Refresh.

New Approach

A "Core for All" interdisciplinary engineering science curriculum.



About the programme

The majority of students join the university on our general engineering degree although entry is permitted on any of our engineering courses: automotive, biomedical systems, civil, electrical and electronic, electronic, manufacturing and mechanical, mechanical, and systems.

These courses share a common first year and one term 'core for all' curriculum¹, with modules agreed by all disciplines, and co-designed and co-taught by academics from each of our discipline research streams.

This connected approach provides a broad interdisciplinary learning experience of shared engineering principles and approaches common to the specialisms offered in the school. In the second term of the second year, students are equipped with technical depth to facilitate industrial and research placements.

At the heart of our degrees is a belief in the core engineering science principles that will enable a multidisciplinary approach to problem solving, the ability to manage projects and communicate ideas, and the capacity to lead, research, design, innovate

and develop products and systems and hence future proof our students careers to a range of developments in engineering and technology in decades to come.

Overview of the new approach

The four-term 'core for all' approach was developed through exploration of essential discipline specific topics and how they relate to - or enhance - other engineering disciplines.

The aim was to avoid curriculum 'silos' by co-developing a diverse range of modules between members from all disciplines. This systems-thinking approach² highlights the integration and interconnection of things, synthesis of ideas and relationships between the disciplines.

In the first year, interdisciplinarity is embedded by the Engineering Design and Systems Modelling modules. Engineering Design runs throughout the academic year and students work in groups on sprint projects in which they are co-located in multi-disciplinary teams and work on increasingly open-ended challenges.

An intensive Systems Modelling project week combines computational thinking with a particular discipline use-case to expose students to problem solving in a random engineering field.

Design and systems thinking are combined in the second year in Electromechanical System Design challenges where students develop instrumentation and control in a design project, again supported by all the disciplines in the school. The universal topic of data science is introduced to equip students with knowledge of data-driven decision-making tools enabling students to use real-world information to identify relationships and patterns and develop models from data³. In the fourth year, engineering students are combined to form multi-disciplinary teams to tackle complex, innovative projects which supports interdisciplinarity by drawing knowledge from across disciplines.

How the programme relates to other New Approaches facets

Following a review of the existing curriculum and benchmarking against the sector, our Industry Advisory Board provided feedback on the 'core for all' aspects.

¹ R. Lillington, C. Mias, C. Lucas, and G. Cooke. "Engineering education has a problem: how do we teach our students about the technology of tomorrow, when it hasn't been invented yet? ". *7th International Symposium for Engineering Education*, University College London, July 2018, UK

² Lucas, C, and Popham, T, 2019. The opportunities and challenges of Systems Engineering in Undergraduate Programmes. ASEC 2019, Leeds, UK. 19-20th November 2019.

³ Popham, T, and Lucas, C, 2019. Data Science: What do Engineers Need to Know? *UK and Ireland Engineering Education Network Spring Colloquium*, Dublin, Ireland. Feb 2019

⁴ Lucas, C., Thomas, T., Thornby, J. and Noel, A., Towards a competency-based peer assessment for engineering group projects using skill descriptors. *UK & IE EER Network 6th Symposium*, Portsmouth, UK. January 2019.

Discipline-specific Industry Advisory Panels then provided input at the module level (for example guest lectures and authentic, industry-led design challenges). Regular, group-based project work is included throughout with the aim that students co-create and share knowledge rather than assign themselves roles and tasks.

We updated our peer assessment process⁴ to highlight industry-desired behaviours and reward transparency, accountability and shared-ownership.

Students are invited to consider their role in diversity and are awarded the highest marks for the way they support others to contribute. Significant investment in financial and human resources, particularly an electronic lab and creating a new Engineering Build Space, has increased authentic projects, creativity and practical work. For example, microcontrollers are introduced in year one. This supports creativity and enables complex projects to be developed.

Leading and managing the change

The change was led by the head of teaching in the School of Engineering, with ongoing input from five discipline specialists (civil, biomedical & systems, electrical & electronic, mechanical, and manufacturing). The advantage of this approach was the head was a new member of staff with no 'allegiance' to decisions made in the past and was independent of the traditional disciplines.

As such proposals and decisions could be challenged, robust debates were encouraged and facilitated, and the process was managed to tight deadlines. A notable part of the process was the curriculum refresh was completed, and changes made, during the marketing process for the next intake. This strategy required regular communications with applicants throughout the recruitment cycle and required university assistance.

The refresh process took around nine months. Staff, industrial partners, existing and past students were involved in the re-design process. External input was sought from respected academics at other sector-leading institutions.

At the outset (existing) students were consulted, via the Staff-Student Liaison Committee, about conceptual changes and the 'core for all' approach. Towards the end of the curriculum development process, the redesigned course details were shared with

the students and focus groups held to feed into final amendments.

Benefits of the new approach

The approach is facilitated via the context of a general school with interdisciplinary research themes and groups which cross discipline boundaries.

This is attractive to both students and employers and we have been able to raise our entry tariff as a result of the changes. By strengthening projects and group work we develop a cohort of collegiate, confident, articulate and resilient engineers who can effectively work together in multidisciplinary and multi-cultural teams. As well as interdisciplinary group work, the structure is evident in individual projects where, for example, civil engineering students pursue projects in structural health monitoring and control of buildings and mechanical engineering students develop computer vision for measurement systems.

The balanced exposure to major engineering disciplines enables students to make an informed choice about the degree programme they wish to study from year two term two. A consequence of this is students explore non-traditional disciplines such as systems engineering or choosing to remain on the general engineering route. This latter degree enables them to form balanced, personalised programmes which leverage their strengths.

We believe the changes in student choices indicate an increased student awareness in the choice they are making and reflects modern industrial needs.

Making the changes: learning points

Our advice would be to start with a vision of what you would like to achieve. We focused on the outcomes in terms of skills, knowledge and understanding that embodies a University of Warwick graduate. We mapped how we could achieve that from our starting position and the changes that would be necessary.

Change requires difficult conversations and equally difficult decisions. Provided these can be justified and meet the vision then the change process is easier. Understand how your organisational structure might hinder, or indeed benefit an interdisciplinary approach and try to promote cross-discipline collaboration in teaching.

For example, we have an excellent teaching relationship with Warwick Manufacturing Group (WMG) and worked with them to achieve the vision.

Practical aspects should not be overlooked such as the academic year, examination periods and timetabling. Making time in the academic year for group work and intensive projects can be a challenge and requires a change of traditional formats. For example, we have formal learning and assessment after the summer examination period. Involve students in the design and development of the changes. Explore students' relationships with research, their understanding of it and what particular topics are of interest. This will help you to make decisions about what they might consider core.

Student feedback

All feedback taken from first year systems modelling module projects:

"A lot of independent learning"
 "Projects were interesting and engaging, all members of the group had to have an idea of what was going on"
 "real world applications of the teaching we've had over the year"
 "the project has improved my knowledge and understanding of thermodynamics, wish it had taken place before the exam"
 "Practical activities strongly support lecture materials"

Key metrics

- The revised programme was introduced in 2017/18 academic year; these students enter the third year in 2019/20
- The intake is typically 325 students across all undergraduate courses each year
- Female-to-male student ratio: 19%/81% in 2017/8 and 21%/79% in 2018/9.

Project work

University of Warwick School of Engineering and Warwick Manufacturing Group

Programme

MEng Final Year Group Project Module ES40 (Various engineering degree streams).

New Approach

Engagement in International Design-and-Build Competitions.



About the programme

Engineering students at the University of Warwick follow a programme of common core engineering content for the first year-and-a-half, before choosing to specialise in one of nine specific engineering streams.

The requirements of accreditation by the various professional institutions specify that a master's degree should permit students to demonstrate competency at project work, both individually and as part of a peer group.

Consequently, all of our Engineering degree programmes specify that students undertake an individual project in their third year; if they choose to progress to the fourth year to complete their MEng, they then undertake a group project comprising 25% of the credit for their final year of study.

Groups are configured so that students work with a range of colleagues from other degree streams, much as they may encounter in an authentic working environment. Characteristics of these group projects form the basis of this case study.

Overview of the new approach

In recent years more opportunities have arisen for students to take part in externally-specified competitions.

Some are enthusiastically supported by the professional engineering institutions. One example is the 'Formula Student' competition, endorsed in its UK format by the Institution of Mechanical Engineers. In this, teams of students from around the world design and build racing cars to stringently defined specifications and compete in annual competitions.

Other opportunities involve competitive tendering to externally-specified and often very demanding criteria. An example of this type of project would be the Warwick University Satellite (WUSAT) group project, which has designed, built, tested, launched and operated low-cost nano-satellites to meet the requirements of a defined mission. This requires engagement with organisations such as the European Space Agency (ESA) and success is judged largely by the standards set by their timelines and review processes.

Through a direct comparison between these competition-based group projects and more traditional, academically-specified projects, this case study considers the benefits to the students' experience and improved attainment of higher-order thinking processes and skills such as problem solving, leadership and team-working.

How the programme relates to other New Approaches facets

This work has been able to demonstrate that such competition-based projects are able to provide significantly improved *Authentic Assessment*¹ and opportunities for *Legitimate Peripheral Participation* (LPP²).

As such, they provide a more realistic *workplace experience for students*, in terms of meeting both financial and time-related deadlines. The also develop skills such as negotiation, marketing, publicity, project management, problem-solving, team working and leadership.

The projects invariably necessitate seeking sponsorship and support in order to meet the significant costs involved and this has most effectively been achieved by engagement with companies involved in related industries and technologies.

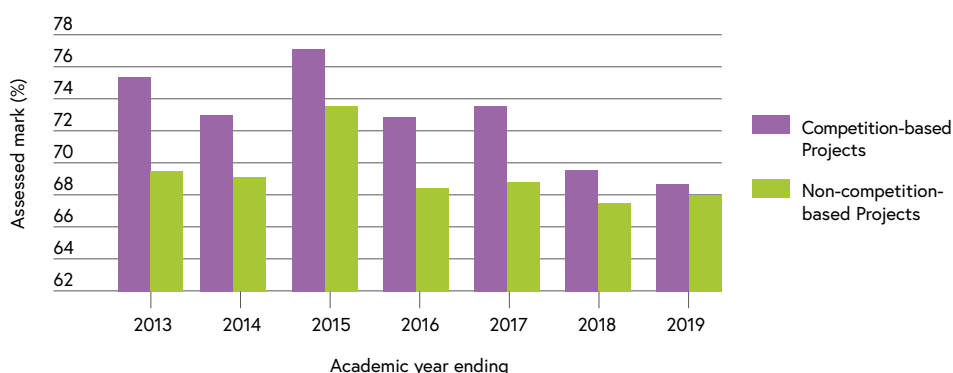
This in turn has very effectively enhanced both the facets *industry engagement in design and delivery* and *incorporating creativity into engineering*.

Leading and managing the change

The projects are led each year by an academic project director and many of the competition-based projects have run repeatedly over a number of years, engaging successive cohorts of student teams and often continuing under the

¹ Gulikers, J., Bastiaens, T. and Kirschner, P., 2004. *A five-dimensional framework for authentic assessment*. Educational technology research and development, 52(3), pp. 67-86.

² Lave, J. and Wenger, E., 1991. *Situated learning: Legitimate peripheral participation*. Cambridge university press.

Figure 1 – Competition-based project assessment

guidance of the same academic with a particular interest in the work.

This has a peripheral benefit of providing academic staff members – who are often in teaching-focused career paths and may not find it easy to work outside of the institutional 'silo' – the opportunity to engage with other academics from the wider international educational sector.

Leadership of team activity is undertaken by the students allocated in each team as one of the essential learning outcomes of the module. The authentic aspects of the competitions invariably enhance the workplace-relevance of the leadership experience and will often involve significant engagement with sponsor companies.

Benefits of the new approach

The whole purpose of this case study is to illustrate the advantages that these 'competition-based' projects have over more traditional 'academically-specified' projects for the students themselves, in terms of many of the facets of the New Approaches initiative.

Our institution has recently started to appreciate that success in these internationally-competed events provides a powerful endorsement of the quality of the courses offered by the University of Warwick. They also help to encourage school-age children to see STEM subjects and engineering as a potential career path. The projects have featured prominently at the Institution's open days and events such as the Imagineering Festival.

Now, we are putting together a more coordinated way of supporting these activities covering the funding of competition entries and shipping built

structures to international competitions. The objective is to better capitalise the publicity opportunities that these activities offer.

Some of the sponsor companies report that supporting these competitions is very helpful in meeting their corporate responsibilities for outreach and societal support.

Making the changes: learning points

These activities are to be strongly recommended, with tangible benefits to all involved.

For students, the learning experience is improved in many areas which are usually hard to address in the traditional academic environment. We see improvements in key employment skills that are increasingly the focus of educational standards and better assessment results.

Academic staff benefit from the opportunity to engage with national and international bodies from an academic or industry focus.

The new employer and student links produce notable benefits for both parties.

Students benefit from experiencing real-world working practices and many have received job offers from their sponsor companies at the end of the project work.

The companies themselves have relished the opportunity to see the students' abilities for their graduate recruitment programmes. This has boosted involvement with the university more generally, fostering research links and even professional development opportunities for their own staff.

Quotation from student

"In addition to all the challenges that we women in engineering face, being the female leader of an otherwise all male team was a demanding but very rewarding role.

The lessons I have learnt throughout my time, coupled with the many skills procured along the way, have been invaluable as preparation for working life after university.

Despite being the most difficult venture that I have undertaken at university, it is certainly among the most enjoyable, rewarding and memorable experiences I have ever had."

Key metrics

- The programme has run for eight years with between six and eight students in each group and 25 groups in each year cohort
- The female-to-male student ratio is 30%-70%
- Over 90% of students are employed six months after graduation.

"Over the 8 year that we have engaged in the international competition, every single student allocated to the project that I am responsible for has achieved a First-Class mark for their Group Project. I have no involvement in the grading of my own team's work and there has been no evidence of grade inflation across the wider cohort."

Industry engagement

Aston University Engineering and Applied Science

Programme
Foundation Degree in Electrical Power Engineering.

New Approach
Work based learning.



About the programme

Aston University is the only UK University that provides a work-based electrical power foundation degree.

The programme is innovative due to the fact that it was developed between industry and academia, working in collaboration with industrial training schemes from the UK's main Transmission operator National Grid and Distribution Network Operators such as SSE and Western Power Distribution.

The programme is academically rigorous, providing industry with a well-rounded engineer who can logically solve problems in the workplace, based on sound academic theory.

Industrial partners have commented on how this approach produces an employee/graduate that can compete and, in most cases, outperform an employee on a traditional level six graduate scheme.

Overview of the new approach

The programme was the first of its kind in the UK to target the skills gap at technician level in the electrical power industry.

Previously, training schemes were focused on craft level and graduate schemes.

The successful delivery of this work-based learning required a close working relationship between our academic team and our industrial partners, to ensure the development of degree which produce graduate employees that have the specific skills required to fill the skill-based gap.

In recent years this working relationship has extended to include students, in the development of the programme curricular and student support.

The development of this tripartite relationship between key industrial employers has led to a number of important lessons learned which are directly applicable to the successful delivery of Degree Apprenticeships in the University sector.

How the programme relates to other New Approaches facets

Our programme also relates to the project work fact of the New Approaches.

The programme has a work-based project module designed to encourage students to use their knowledge to solve a problem using sound engineering logic, which allows it to meet the requirements of Ofgem and is ultimately cost beneficial to the company. One of the Ofgem metrics that Distribution

Network Operators (DNO) are graded on is how quickly they restore supply following fault conditions.

The funding received by the DNO from Ofgem is linked to restoration of electricity supply. Students are encouraged to identify project that improve DNO's standings in metrics such as these.

Leading and managing the change

The change was led by a team of experienced academics who have a relevant industrial and work-based learning experience and industrial partners from the transmission and distribution sector. Due to the work-based experience of the academics involved, trust was established quickly with industry to develop a bespoke learning programme which has naturally evolved over ten years to reflect the requirements of industry.

The introduction of programmes that focused on students who were working whilst studying required the development of a different type of degree in relation to teaching delivery and student support.

This has meant the academic team have had to develop a programme that did not always align with the more 'standard' on-campus academic delivery and was required

to work with the University to influence quality changes to enable degree delivery.

For example, the academic team worked with university to make a change to weighting of assessment to satisfy the requirements of accrediting bodies such as the IET.



Benefits of the new approach

The programme is delivered alongside a number of industrial partners who plan their training programmes to fit in with what students are learning at university.

This gives the student greater context for what they have learnt and validation that what is being taught is relevant to their future career.

The academic rigour of the course ensures students develop a logical pattern of thought and a deep understanding of the basics of electrical power engineering.

This enables students to think for themselves when problem-solving in the workplace. This is clearly of direct benefit to the employer who wishes to upskill its workforce.

Making the changes: learning points

Consult closely with industry to ensure that students are treated no differently to the way they are in the workplace, in terms of punctuality, attendance and behaviour.

The graduate at the end needs to have a strong academic background and we believe that assessment needs to be rigorous and have a higher exam weighting in comparison to coursework.

Our experience is that students that stay at the same hotel can have a tendency to collude on coursework. Whilst this is an opportunity to encourage peer learning, excessive collusion can result in holes in students' knowledge.

There can be a high proportion of students accepted onto the programme who are mature candidates who have not been in the education system for many years.

As a result, they tend to be weak on basic maths. The programme leaders have worked with colleagues in the learning development centre to offer extra maths support where appropriate.

Students are not full time on campus and can be living in opposite ends of the country, the programme has developed its online VLE to support these students and the ability of the LDC to run online seminars and respond to maths difficulties via email.

Key metrics

- The programme has run for 10 years with an intake of around 45 students per year
- The female-to-male student ration was 20%/80% in 2019/20
- 100% of graduates are in employment after six months.

Project work

Brunel University London Department of Mechanical and Aerospace Engineering

Programme
Professional Engineering Applications and Practices.

New Approach
Using Mentors to Learn How to Analyse an Engineering
Business and Develop Reflective Practice.



About the programme

A need was identified to develop explicit reflective practice amongst engineers in the Department of Mechanical and Aerospace Engineering.

This approach is embedded in two compulsory modules: one in the second-year, the other in the final-year of the MEng course.

Reflective reports are completed as part of each compulsory modules' assessments. The final-year MEng students learn to mentor and coach second-year teams of five or six students as part of their module in Strategic Management: Innovation and Enterprise, where the emphasis is on bringing about change through managing people.

The second-year teams, to which individuals have been allocated, work collaboratively researching a presentation about an organisation that was proscribed for their team.

Their MEng mentor often has an interest or connection with that organisation for example they may have been on placement or be seeking employment with them. An extensive portfolio of skills is developed during the exercises.

Overview of the new approach

Project work, as an experience, is supposed to be an authentic representation of how industry carries out its business.

The charge has been made that academia tends to be poor at preparing and supporting individuals in the team aspect of projects; that we arrange groups in the hope that individuals learn from the experience, but we do not always require them to account for it.

In this initiative, we place emphasis on individuals reflecting upon their experience of working together, and with a mentor, who is a few years ahead of them in experience in the same course of study.

In the forthcoming year, we will have mentors who have had both the experience of being mentored in doing this exercise, and of having completed a one-year industry placement.

The hope is that many more second-year students will follow this route of completing the placement-year, as these tend to become engineering employees more engaged with the industry.

How the programme relates to other New Approaches facets

Each team carries out an analysis (case study) of an allocated business that is currently advertising opportunities for workplace experience for students, either in the format of a one-year placement or summer internship.

It has been noted that engineering students, as many young people, seem disinclined to apply for roles anywhere other than in well-known brands for their initial employment.

To offset this attitude, the project is designed to raise awareness and validity of less well-known organisations in the bigger brand supply-chains.

This is done both in the research that teams carry out, and through exposure to engineers who have worked for such companies during their placements.

Leading and managing the change

In 2014, subsequent to Brunel being made an award under the HEFCE Postgraduate Support Scheme, I was given the opportunity to lead the 'Women in Engineering' programme at Brunel.

Having set up MentorSET (a national, cross-discipline, cross-organisation mentoring scheme, to develop self-confidence in women engineers) whilst I was President of the Women's Engineering Society, I developed a scaled scheme within Brunel.

As we debated the advantages in professional development to experienced engineers of being trained in mentoring skills, I posited that there were benefits to training final-year MEng students to be mentors to their younger peers; that this would help develop a community of engineering practice.

I successfully bid for a 'BrunelTeach' award, and instigated the change of the final-year MEng course to include the equivalent of about 5-credits focused on the use of coaching and mentoring to support change in organisations, including the practical exercise of learning to mentor a team from a subsequent year-group.

Benefits of the new approach

The new approach benefits all MEng students in their gaining experience of coaching and mentoring less experienced students within the boundaries (and oversight) of their degree course.

At least one recent graduate commented that this had directly supported his successful application to a trainee management position in a facilities company, where his experience had been discussed in his interview.

Second-year students have also commented that it is 'useful' to have contact with a student who has been through their course, and that they have gained insights into all aspects of the degree through this contact.

Of course, students may socialise across years in any case. It has been noted that fewer of our students live on campus (rather, they live at home), and many are commuting for an hour or more each day, so that ad hoc socialisation is less likely. By

adoption of this approach, the university knows that bridges are being made between groups.

It is anticipated that these may contribute to the individual engineer's professional network as their career progresses.

Advice you would give to others looking to make similar changes

It is important to clearly brief, through lectures and other resources, both groups of students in their role (as mentor or mentee) and the role of others, providing them with a framework of support if they feel that someone is 'not pulling their weight' or seeming to be disruptive. Often this leads to understanding the diversity of others' commitments outside university studies.

Endorsement of the use of mentoring and coaching is helped by having guest speakers from industry, who can discuss how they are used in their companies; and having registered Chartered Engineers discuss the need for reflective practice supports the relevance of the assessed reflective report. In turn, guest speakers can promote the opportunities for employment that they have in their organizations.

It is advisable to discuss with all students the differences in teaching, coaching and mentoring; and the need to become an 'autonomous learner' in the practice of engineering.

They need to be assured that mistakes are acceptable, although an unrehearsed presentation is not; and the insight of owning an experience through the use of personal pronouns is the value-added to their learning outcome.

Quotation from student

"The coaching and mentoring content was good... both informative and relevant for the practical aspect."

"I... enjoyed my time helping the students I was paired with. I found it interesting learning about techniques. I also found it interesting when leadership techniques were touched upon..."

Key metrics

- The programme has run in this format since 2016
- Around 200 second-year and 50 final-year MEng students participate each year
- The female-to-male student ratio is 90%/10%
- The percentage of students in employment after 6 months is: 80.4% for aerospace and 68.4% for mechanical engineering (based on 2016/7 figures).

Industry engagement

Limerick Institute of Technology Department of Mechanical and Automobile Engineering

Programme

B.Eng. (Honours) in Precision Engineering; B.Eng. in Precision Engineering; Precision Machining and Quality Control Apprenticeship – in development.

New Approach

Strong interactive Industry involvement in the design and delivery of the programme, forging new links with the Irish and UK precision engineering industries through engagement with industry and academia.



About the programme

Both the government agencies in Ireland and the precision engineering industry have identified that there is considerable difficulty in finding suitably qualified technicians who have the appropriate skills to operate effectively in organisations as precision engineering technicians.

Precision engineering talent at engineer level is also scarce. Historically, this market was catered for by graduates from the toolmaking apprenticeship, but the technology and skillset required by industry has significantly changed over time.

This programme was designed and developed initially as a level seven technician programme in full collaboration with the Precision Turned Parts Manufacturing Association (PTMA) and Limerick Institute of Technology (LIT) mechanical engineering staff where students attend LIT classes for part of the teaching week and work in Industry for the remainder of the week.

Following from the success of this programme in meeting the needs of the precision engineering industry, an honours degree was then developed in collaboration

with the PTMA which is currently offered in LIT as an add-on programme to the level seven programme and as a stand-alone ab initio programme.

In addition, LIT was successful in securing permission from the Apprenticeship Council and the Higher Education Authority in Ireland to create a new apprenticeship in Precision Engineering with the PTMA as our consortium partners in that venture. This apprenticeship is currently in the development stages.

Overview of the new approach

During the design and development of any new programme, industry is consulted at the very early stage for viability and then when the programme is designed to make minor changes and additions.

The PTMA are an Irish national representative body for the precision engineering industry comprising over 40 Irish precision manufacturing organisations who meet in LIT every two months.

As an outcome to these meetings, they asked LIT to develop a technician qualification in precision engineering as they were unable to find suitable graduates with the appropriate skillset.

From the outset, a subset of the PTMA group and five LIT mechanical engineering staff came together to design the programme where students would be taught in LIT for two days and work in Industry for three days each week.

This approach ensured that the skillset needs of the precision engineering industry was included in the programme while ensuring that the students have a balanced engineering technician programme that meets the needs of the Associate Engineer professional engineering title awarded by Engineers Ireland.

The PTMA organisations, agreed among themselves, the essentials of salary and how much these students would be paid to travel to LIT, so that there would be uniformity across the sector.

It is the degree of interaction with Industry in the design and delivery of this programme that makes this initiative unique.

How the programme relates to other New Approaches facets

This programme allows students to gain experience at work and University. It has been designed to ensure that some of the graduate skills are taught in the workplace and others in LIT. The benefit of having such close collaboration during the programme design phase has enabled this work-based learning to be incorporated into the programme.

Creating a programme that meets industry needs while ensuring the right balance of fundamental engineering concepts and practices was the challenge for the design team. Bringing this design team through the various stages of the LIT academic new programme approval process was also a challenge.

One benefit of our close links with industry was the donation of cutting-edge precision engineering equipment to allow students to have the necessary skills on graduation.

Leading and managing the change

The LIT mechanical engineering staff have strong links with Industry where many of the final year projects are industry-based projects.

Some of the staff have links with the PTMA and offered LIT as the base for their bi-monthly meetings. While attending one of these meetings, the LIT staff were asked to work with the PTMA in educating graduates with the appropriate skillset to meet the needs of the precision engineering industry.

The LIT staff discussed the possibility of creating this new programme with management and then prepared the documentation to bring the proposal to academic council.

One member of the mechanical engineering team became the **programme champion** and has led all interaction with the PTMA and Gauge Tool Manufacturing Association (GTMA), a UK based precision engineering professional association.

The programme champion prepared all documentation for the successful completion of the LIT new programme approval process, leads the development of the new apprenticeship programme and all interactions with the Apprenticeship Council in Ireland and leads the preparations for the international conference with the PTMA/ GTMA each year.



Benefits of the new approach

LIT has developed two new programmes in precision engineering which are closely linked with our mechanical engineering programmes.

There is a cohort of students on each of these programmes at present and the programmes are offered to prospective students entering University each year through the Irish system for applying for higher education.

LIT has also been successful in gaining permission from the Apprenticeship Council in Ireland to develop and run a new national apprenticeship in precision engineering.

LIT will be the Irish National Co-ordinating Provider for this apprenticeship. LIT are working in close partnership with the PTMA in the development of this apprenticeship. As an outcome of this level of interaction between LIT and the PTMA, LIT have hosted an international Conference in LIT for the last three years with the PTMA/GTMA.

This conference is always fully booked with over 600 attendees and 100 UK and Irish-based exhibitors. LIT also hosted the European SID conference as part of this yearly international conference last year.

Making the changes: learning points

When the skillset needed by Industry is changing rapidly, it is imperative to work closely with that Industry to achieve the desired graduate skillset.

Bringing the leaders of the Industry into the programme design throughout the design and development of the programme is essential to ensure the appropriate outcome.

If it is possible to meet with the Professional Body representing the Industry (in our case the PTMA), and interact regularly with them, then other programme and CPT opportunities may arise. In our case, the new apprenticeship, at level six, emerged from this collaboration.

Key metrics

- The programme has run since 2017 with around 15 students per year
- There is a 100% employment rate for our graduates – this is because students are employed on a training contract and are expected to remain with the employer following graduation.



Project work

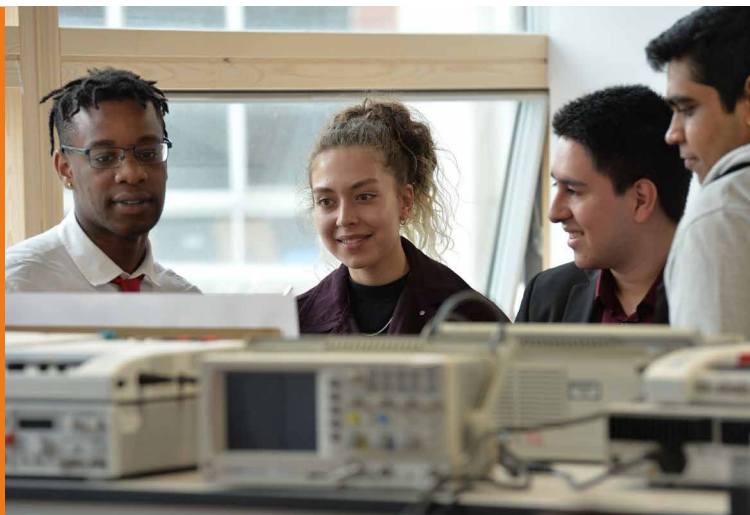
Queen Mary University of London School of Electronic Engineering and Computer Science

Programme

Strengthening technical thinking through writing: a pilot study in the Design and Build Group Project in Electronic Engineering at QMUL.

New Approach

Exploring the links between cognition and language to hone the precision and exactness of engineering thinking.



About the programme

In the School of Electronic Engineering and Computer Science (EECS) we are developing a trans-modular, cross-programme initiative to deliver a coherent and systematic integrative teaching of technical thinking and writing across the undergraduate curriculum.

This "Technical Thinking and Writing pathway" (TTWP) recognises the role of language as a meaning-making tool, and the relationship between the precision with which students use technical language and their higher cognitive skills - in particular their ability to use insightful analysis and critical thinking - in developing innovative engineering solutions^{3,4}.

TTWP is based on generic engineering and scientific methods. It focuses on various forms of expressing abstraction in the process of analysis and modelling, develops awareness of the exact, precise, and concise nature of technical communication, and makes clear the purpose of technical writing and its relationship to thinking.

Here we are reporting the results of the pilot we ran in the second year-group project module of the BEng course in electronic and electrical engineering in 2019.

Overview of the new approach

In our school, students do group projects in the second year and individual projects in the final year. Traditionally, the focus of project-based learning has been the development of technical skills. However, an explicit development of thinking, communication, and writing skills can advance the development of higher cognitive skills of abstraction, modelling, and interpretation, required in engineering problem solving^{6,8}, especially if done within a discipline-specific professional context. Such approach can also contribute to the development of conceptual clarity and reasoning when solving problems and answering exam questions^{3,4}.

Our approach generalises cognitive processes of problem solving and relates them to student declarative knowledge,

by developing students' use of language, supporting the process of meaning-making^{1,2}.

In the Design & Build Group Project in Electronic Engineering, we made explicit the system of thinking that underpins the problem-solving process by grounding activities in the generic engineering method.

Our interactive workshops focused on writing forms that help analysis and modelling through various levels of problem abstraction.

We used the idea of "argument pyramid" and provided annotated texts to reveal structure of critical thinking. We devised writing tasks directly related to engineering challenges students were facing, to sharpen their rigour in project execution^{5,7}.

Evaluation of the pilot shows that students felt they hugely benefited from this approach and felt ready to face the challenges of the final year project.

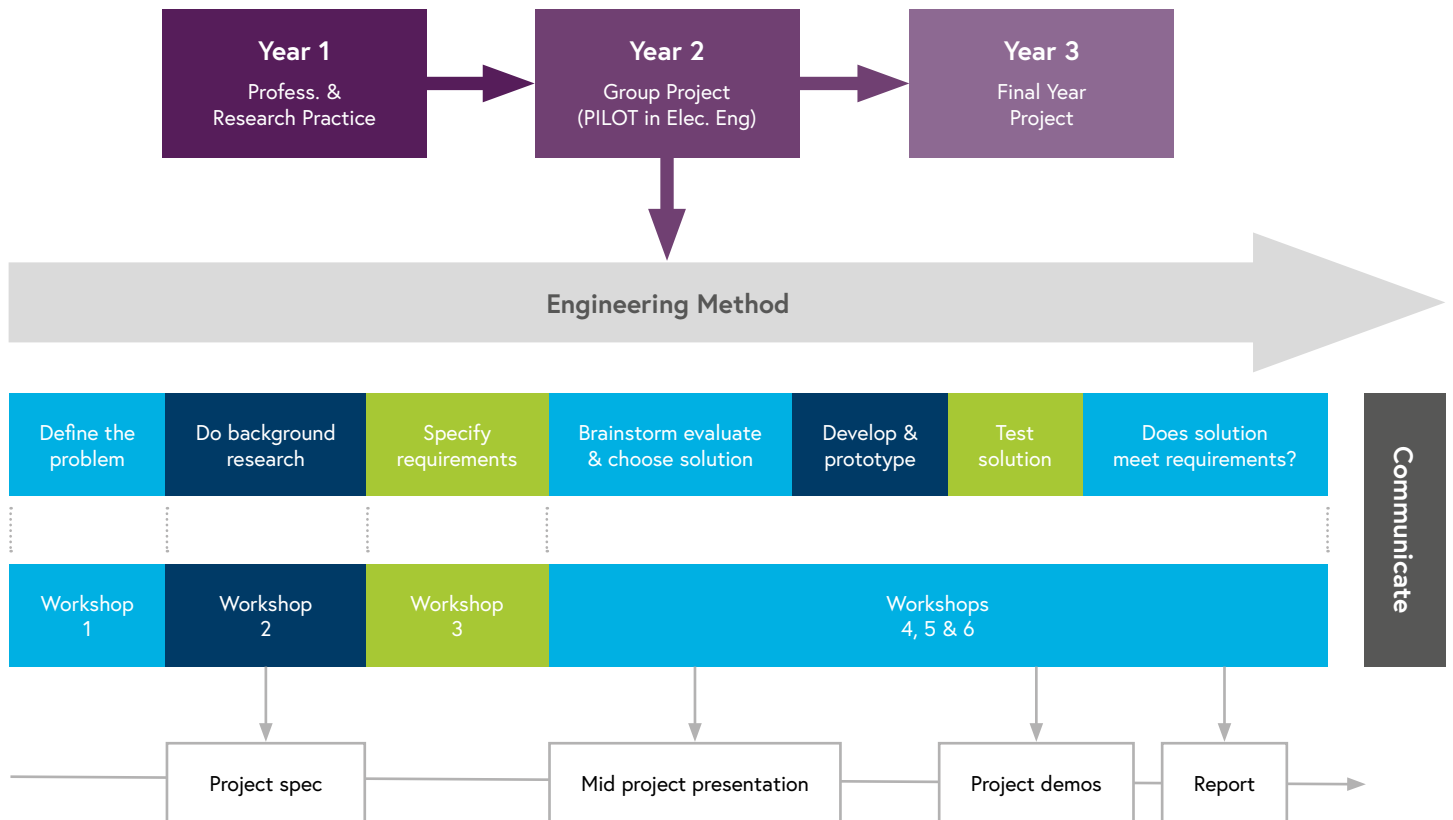
¹ Beer, D. and McMurrey, D. (1997) *A Guide to Writing as an Engineer*. New York: Wiley & Sons.

² Coffin, C. and Donohue, J. (2014) *A language as social semiotic-based approach to teaching and learning in higher education* (Language Learning Monograph Series). Chichester, West Sussex; Malden, MA: Wiley-Blackwell.

³ Curry, M. and Hanauer, D. (2014) *Language, Literacy, and Learning in STEM Education. Research Methods and Perspectives from Applied Linguistics*. Amsterdam, Philadelphia: John Benjamins Publishing Company.

⁴ Drury, H. (2001). Short answers in first-year undergraduate science writing. What kind of genres are they? In M. Hewings, *Academic writing in context: Implications and applications*. Papers in Honour of Tony Dudley-Evans. Birmingham, UK: University of Birmingham Press.

Figure 1 – TTWP & pilot structure



How the programme relates to other New Approaches facets

In engineering, critical thinking is the basis of creativity and innovation. By developing critical thinking, through exact, precise, deliberate and insightful writing, we are providing our students with the tools of creative inquiry and innovative solution-finding.

Asking pertinent, deep and probing questions, which in turn lead to robust designs, is a skill that needs to be developed in undergraduate students.

To do that, we used a range of written forms to unpick aspects of engineering thinking and show ways to gain insights that lead to creative synthesis: state-space abstractions of processes, logical and physical block diagrams of system architectures and its subcomponents,

flow-charts, concept maps, as well as listing questions with reflection on how the answers might affect technical thinking.

Applying these writing and thinking tools in the broad context of engineering process (instead within specific technical subjects) helped our students become more agile and versatile in using them when dealing with new problems, fostering engineering creativity.

⁵ Gourlay, L. (2009) Threshold practices: becoming a student through academic literacies. *London Review of Education* 7 (2), 181–192.
⁶ Halliday, M.A.K., & Martin, J.R. (1993). *Writing science, literacy and discursive power*, Basingstoke: Falmer Press.
⁷ Land, R., Meyer, J. and Flanagan, M. (2016) *Threshold Concepts in Practice*. Rotterdam: Sense Publishers.
⁸ Lievens, J. (2012) Debunking the 'Nerd' Myth: Doing Action Research with First-year Engineering Students in the Academic Writing Class. *Journal of Academic Writing*, 2(1), 74–84.

Figure 2 – D&B group project results

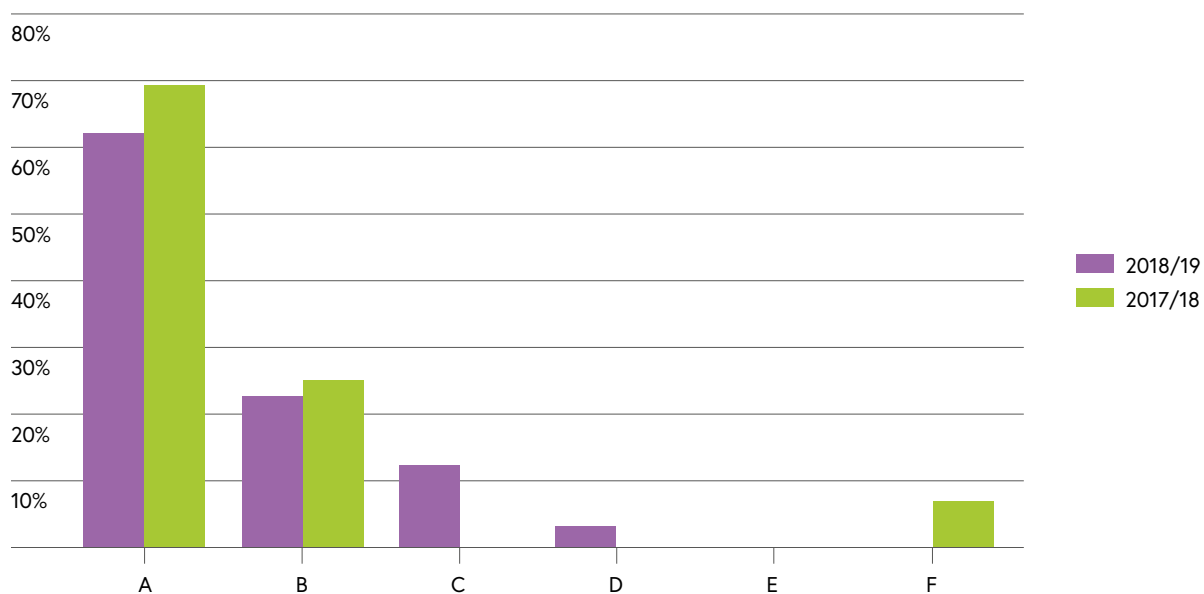
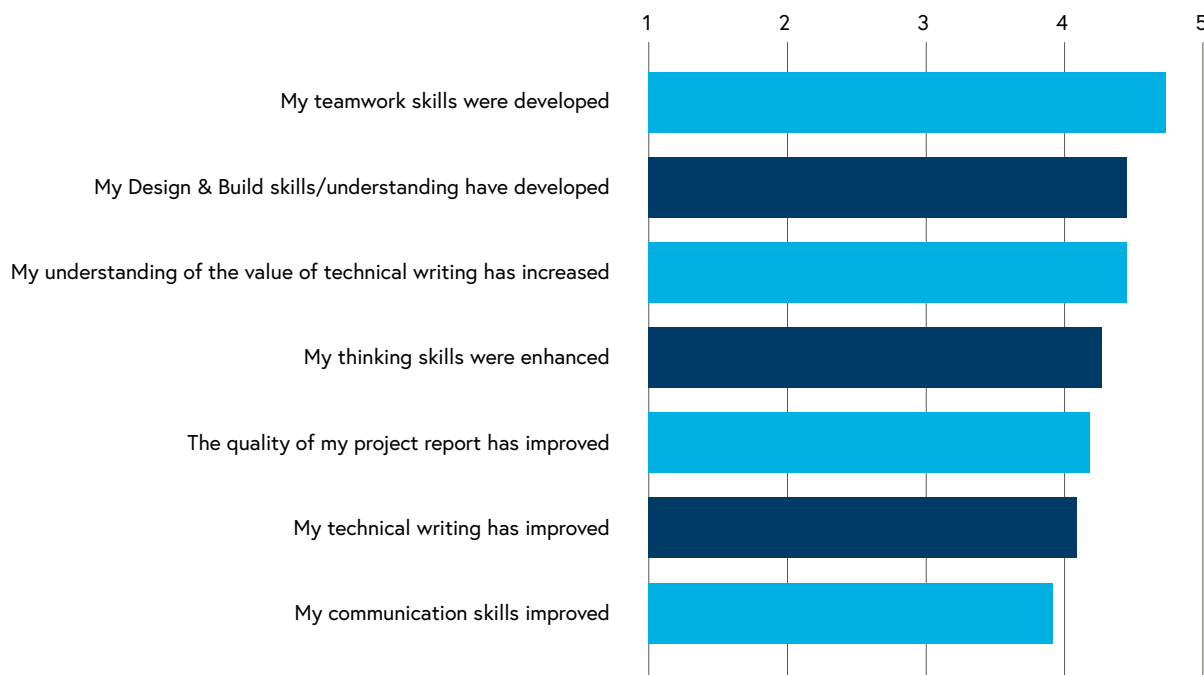


Figure 3 – As a result of the group project module





Leading and managing the change

The change was motivated by increasing awareness of pedagogical challenges we face, in the climate of the rising performance, employability and financial pressures in higher education.

Critical to the change was the enthusiasm and close collaboration of a few academics and pedagogic specialists (the Learning Development team) over the preceding three years, during which our understanding of the educational needs and how to address them had crystallised.

While there was support in principle from senior management when the project was proposed, this was not reflected in practical support in terms of resources given. We decided to start the program anyway, as a pilot, on a smaller cohort of electronic engineering students.

The pilot results provided evidence of both the pedagogic need and the effectiveness of our approach. This has cemented support for expansion of the initiative into the final year project module, starting in autumn semester 2019/20.

Recognition of the need by the Director of Education was critical in enabling the change, since it relies on additional resources, of both demonstrators and staff, and appropriate allocation of time in our workload accounting systems.

Since starting the pilot, a liaison group has been formed and the allocation of time has now been defined (about 70 hours per module organiser, for modules participating in the TTWP; more for the TTWP project lead).

Benefits of the new approach

Our approach resulted in qualitatively better projects and technical reports, happier, more engaged and more motivated students, and, as a side effect of the initiative, more rigorous but fairer assessment of project work.

By expanding this to final year projects, we will bring about a step change in student attainment overall, given the importance final year projects have on the students' final degree classification.

We will also address the dual challenges of giving students the feedback they are looking for and ensuring their greater overall satisfaction with the learning experience at university.

Making the changes: learning points

A small but dedicated multi-disciplinary team comprising engineering specialists – EECS lecturers – and pedagogic specialists – linguists from the Learning Development team – provided the winning mix of skills and insights that enabled the design of this complex intervention with multi-dimensional educational goals.

We recognise the invaluable role of pedagogic experts as facilitators in this project: they sought exactness in our formulation of aims, expectations and desired learning outcomes, and hence brought a fresh, exacting rigour to the project. This gave us confidence in the design of the intervention and the evaluation of its impact on students' learning.

We therefore recommend, for a change of this scale, that teams are not too large, and that they comprise a mix of expertise, both discipline-specific and educational or pedagogical.

Recognition of the educational need, and hence the buy-in from the director of education (or an equivalent) is critical in securing resources on the ground.

Student feedback

"Extremely useful in preparing yourself for final year project. This module really piqued my interest in the subject matter."

"There was a lot of useful workshops that helped our group get through the project."

"Very good module. My favourite of the semester."

Key metrics

- This is the first year the programme has run. Its success with the 32 students who participated in the pilot means it will now extend to other programmes in the school – a total of 300 students across all programmes
- Female-to-male ratio: 6%/94%.

— Broadening student diversity

The Open University School of Engineering and Innovation

Programme
BEng/MEng General Engineering.

New Approach
Creating an integrated engineering curriculum
for part-time distance learners.



About the programme

The undergraduate Engineering Programme at The Open University incorporates BEng (Hons), integrated MEng, BEng (Hons) top-up and Foundation Degree.

It is aimed at part-time, distance learners and is open access – that is, there are no academic entry requirements (except for the BEng (Hons) top-up).

The programme offers general engineering degrees with specialisms including Electronics, Energy and Sustainability, Engineering Design, Environmental Technologies, Mathematical Methods and Mechanical Engineering. [Figure 1 BEng topic routes for study].

The programme can be studied flexibly, enabling students to work alongside their study with the majority of students being in full-time employment.

We have reconfigured the programme to incorporate mathematics teaching in context and subsume professional development planning at every level.

The programme incorporates a blended learning pedagogy with week-long residential schools, enabling students to gain practical laboratory experience, alongside the award-winning Open

Engineering Laboratory which gives students access to remote experiments and simulations. Approximately 1100 students enter the programme annually supported by a network of over 200 Associate Lecturers.

Overview of the new approach

Until 2016 the mathematics required to study engineering at The Open University was taught almost exclusively through modules aimed primarily at first year mathematics students.

Students frequently complained that they could not see the relevance to engineering and that many of the concepts appeared too abstract.

The retention and progression statistics for engineering students showed that less than 40% were successfully completing a compulsory mathematics module and those that did pass were most likely to have already studied the subject at 'A' or HE level.

This clearly impacted on the sustainability of the programme, but more worryingly was failing students who were entering with low previous educational qualifications or who did not have a background in engineering.

Our aim in reconfiguring the curriculum was to ensure that mathematics was taught in an engineering context at the point

that it was required and that we enabled successful study for a diverse student population, not just those came with pre-existing skills.

Similarly, Professional Development Planning (PDP) had previously been covered by specialist modules which were disliked by students and were largely aimed at those already employed in the engineering sector.

Recent research has shown that our student body is changing, with a much higher proportion employed in other sectors and wanting to change careers.

This is particularly noticeable among women where 44% reported that they had no experience of the engineering sector compared to 17% of male students.

How the programme relates to other New Approaches facets

We have taken an interdisciplinary approach to reconfiguring the engineering curriculum, working alongside colleagues from mathematics and statistics, design, computing and communications, and physics to ensure a broad-based curriculum which incorporates key skills.

By integrating mathematics teaching, our focus is on 'mathematical thinking' skills' and students' understanding of a problem,

¹ Boaler, J. (2016) *Mathematical Mindsets*. San Francisco: Jossey-Bass

Figure 1 – Undergraduate Engineering Q65 BEng from October 2019

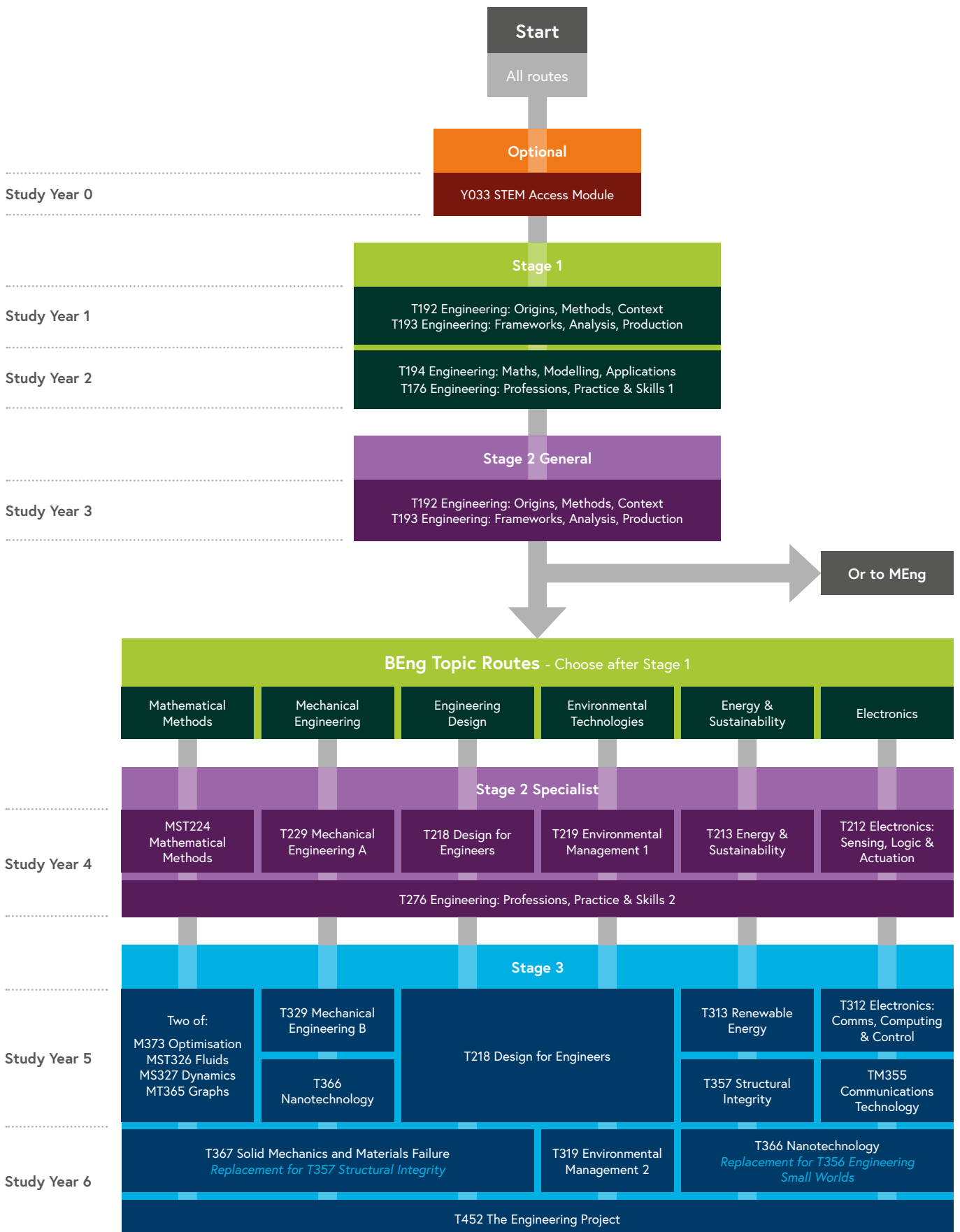
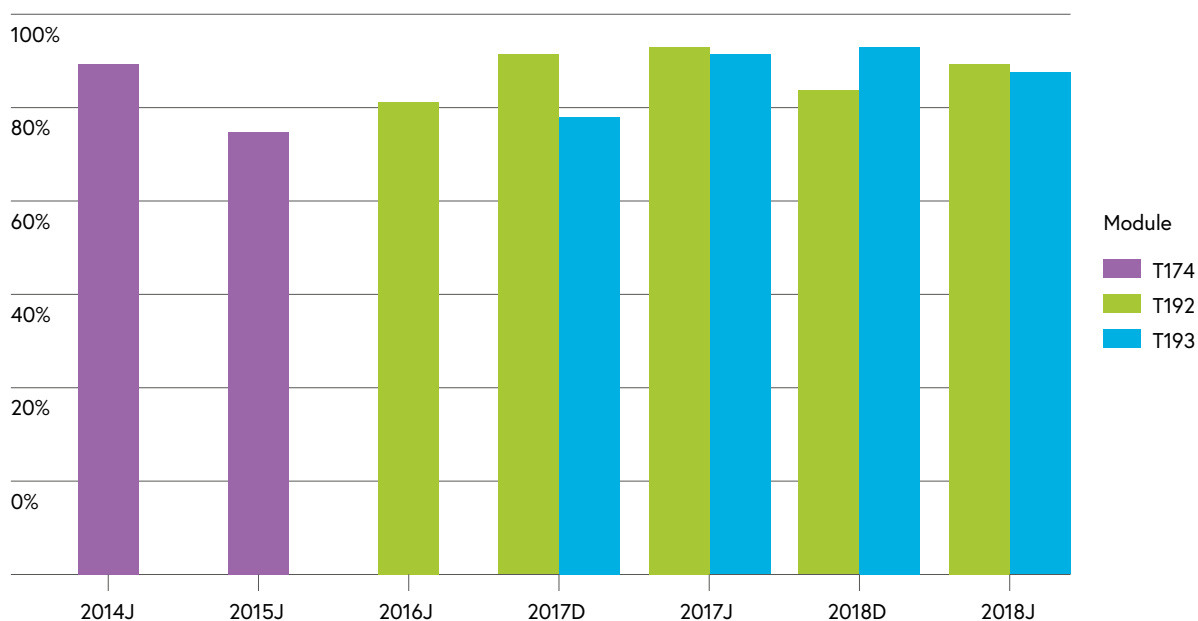


Figure 2 – Overall satisfaction rate EPC



rather than repetition of techniques or reproduction of examples.

We are currently working to ensure that diversity and inclusivity becomes part of the core curriculum, through the appointment of a Royal Academy of Engineering Visiting Professor (Dr. Jan Peters), so that students enter the workforce with a good understanding of the issues which face the engineering profession.

Our aim is to increase participation by underrepresented group and reverse the attainment gap often experienced by students from minority ethnic groups.

Leading and managing the change

The change was led in 2013 by the Director of Teaching (DoT) in the School of Engineering and Innovation working alongside the Qualification Leads².

The DoT had examined pass and progression statistics for engineering students over a number of years and identified that they were consistently failing a compulsory mathematics module.

Discussions held over the course of a year, with academic staff, Associate Lecturers and students led to the formulation of a strategy to incorporate mathematics and PDP teaching into the core engineering curriculum.

Although the problem had been identified by the DoT the solution was agreed on collectively, so there was buy-in from the majority of engineering academics.

This was vital as modules at The Open University take approximately two years to produce and the reconfiguration involved almost all engineering staff in module production over a sustained period of time.

We have been able to lead and manage the change because it was clearly evidence-

based, and we involved as many people as possible in the decision-making processes about curriculum content and pedagogy.

The reconfiguration is ongoing, and the evidence of significantly improved retention and progression is keeping colleagues motivated even though they currently have high teaching workloads.

Benefits of the new approach

Increased retention and progression clearly bring financial benefits to the university. However, there has also been an improvement in the way that students view the curriculum.

Both the BEng (Hons) and MEng cohorts studying the reconfigured curriculum from October 2016 showed an improvement in the percentage of students successfully completing 90 credits of L4 study in a 21-month period compared to previous cohorts.

² Morris, C, Goodyear, A and Organ, SJ; *Developing a sustainable engineering curriculum for part-time distance learning students, New Approaches to Engineering in Higher Education*, London, 2017

The pass and progression rate for the BEng (Hons) students increased by 66% over the previous curriculum while the improvement for the smaller cohort of MEng students was 19%.

Student satisfaction with the reconfigured curriculum is improving over the presentations as shown in **Figure 2 [Overall satisfaction rate – old and new curriculum]**.

There has been a steady improvement in student satisfaction on the first compulsory module (T192) since its first presentation in October 2016 from 81% to 90% for the October 2018 cohort. A similar improvement is shown for the second compulsory module (T193) from 79% to 88%.

The reconfiguration has also brought benefits for staff development and team working.

Making the changes: learning points

The most important piece of advice is to 'do your research' and provide evidence for any changes backed up by appropriate literature.

Academic staff can be, understandably, very protective of their curriculum and the way it is taught, and it would not be enough to rely on anecdotal evidence or student feedback (although that is important).

Our changes meant that funding that would have previously gone to one School (Mathematics and Statistics) was diverted to another (Engineering and Innovation), having an impact on student numbers and consequently full and part-time staffing levels.

We would not have been able to make the significant changes that we have to our engineering curriculum without solid evidence presented at Programme, Executive Dean and University level.

We would also advise that proposed changes are thoroughly discussed and agreed by those who would be tasked with making the changes, so that there is input and buy-in at every level. Keep colleagues informed, so that the impact of their hard work is communicated and rewarded.

Finally, give colleagues resources and time to investigate alternative pedagogies, so that they are fully informed.

Student feedback

"I am particularly pleased with how the mathematical content is taught. It makes a lot more sense to develop the maths alongside the core subjects. It helped me to understand how the maths is relevant and applied. I have previously studied pure maths in isolation but did not enjoy it to the same extent. Using maths within an engineering context is a big improvement it helps to animate the subject."
(T193 student)

Key metrics

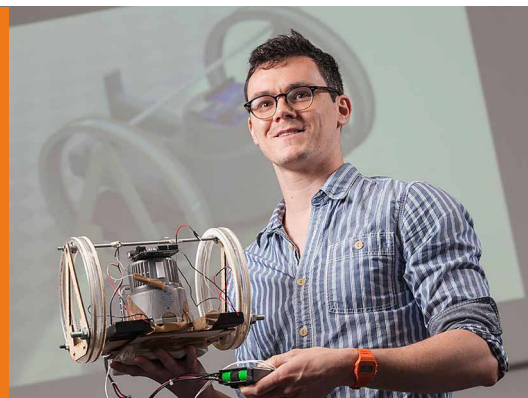
- The programme has run in the new format since October 2016 with the total numbers across all programmes rising from 1,340 in 2016/17 to 1,568 in 2018/19
- The female/male student ratio is 11%/89%
- 15% of our students are classified as low socio-economic status; 30% have low previous educational qualifications (below 'A' level); 10% have declared a disability; 10% identify as BAME
- In 17/18 year 80% of our students were in full-time work and 8% in part-time work at the start of their studies. Our students tend to be promoted or change career, rather than starting employment for the first time.

Interdisciplinarity

University of Bath Departments of Mechanical Engineering (MechEng) and Electrical and Electronic Engineering (EEEng)

Programme
MEng Integrated Design Engineering.

New Approach
A new studio-based MEng Engineering Design degree programme integrating mechanical, electronic and software skills.



About the programme

The Integrated Design Engineering (IDE) course is a collaboration between Departments of Mechanical Engineering (MechEng) and Electrical and Electronic Engineering (EEEng) which aims to create multidisciplinary design engineers of the future.

IDE is a course that builds on technical engineering skills gained in years one and two with a creative design and innovation focus in years three and four.

Students from both departments can join after two years of discipline specific studies (MechEng or EEEng) and then complete a further two years to attain an MEng in IDE.

As part of the latter two years there are five mandatory Design-Make-Test (D-M-T) units. The units are run in a short, intensive fashion. They last four weeks with coursework-only assessment in team-based open-ended project work.

How does your programme exemplify a new approach?

Our programme focuses on interdisciplinarity. As part of its design, we focused on creating a degree which would provide rich learning experiences associated with multi-disciplinary approaches to problem-solving.

We enable students working in multidisciplinary teams to gain considerable experience in creative concept generation; using engineering fundamentals and principles of systems engineering to progress a designed solution; managing the design process; and delivering working prototypes.

As part of the programme development, we reflected on the skills that engineers need now. Popularized by Tim Brown, CEO and president of IDEO, is the idea that a T-shaped skillset is the best for a designer. It means a designer has deep competence in some area and decent knowledge in the rest of the skills.

In the degree, students have some choice how they choose to develop their own learning within their team projects.

Graduate destinations range from entrepreneurship and start-ups through to consultants and in-house design engineers.

In the latter context, employers are likely to value the vertical part of their 'T-shape' skills, whereas in the former types of organisations the horizontal part becomes critical in being able to complete new product development or innovation projects.

We encourage students to take charge of their own learning and consider whether they want to develop themselves more horizontally or more vertically.

How the programme relates to other New Approaches facets

The programme supports project work, creativity and industry engagement through the new Design-Make-Test (D-M-T) cycles and studio-based learning which are core elements of the programme. The units are run as shorter and more intensive sequential projects lasting 4-5 weeks.

The studio environment encourages a hands-on, collaborative approach: encouraging creativity and peer-to-peer learning. D-M-T units also include tutor support/mentoring from external design practitioners.

As part of the course development we have systematically evaluated the impact professional practitioners have had on the learning process. Each of the units had different levels of professional practitioner engagement ranging from: none; to the practitioners developing, delivering and assessing elements of the unit.

So far, we have found that the practitioner engagement approach has mixed results. They do add inspiration and realism to the units' engineering context and students value practitioners' insights into real design processes. However, students are concerned about the ability of practitioners to mark consistently and the potential for assignments which are too constrained.

Leading and managing the change

The department of mechanical engineering has a culture of continual improvement of our degree programs, based on student feedback.

One part of student feedback has always been that our design specialism degree within mechanical engineering did not 'contain enough design'.

The resource intensity of teaching specialist studio-based design projects, and the drive towards teaching efficiencies through sharing units across the department, meant that it was very difficult to respond to this particular feedback.

However, an opportunity arose when our department was pitching to a major funder for a new design building for the faculty of engineering.

As part of this pitch, our core educational team needed to put together a radical proposal for a new creative, design-led degree programme in mechanical engineering.

Although the pitch did not result in funding for a new building, the educational team had caught the imagination of the faculty. The educational team was then tasked with delivering the educational ideas within our existing building. Initially, this was led by an external Professor of Practice. However, as the project progressed experienced internal staff were required to drive developments through to fruition.

The main people involved were the degree theme leader for design, the director of teaching and learning, the dean and the assistant registrar.

Benefits of the new approach

The new degree builds on our existing success across joint mechanical and electrical engineering delivery.

Our existing integrated engineering program (IMEE) celebrated 10 years of success last year. Our new program (IDE) focuses on design and interdisciplinarity across those two departments.

The new program has also led to new educational links with our department of architecture who have been consulted at many stages about the practicalities of studio-based projects and assessment.

The university has seen an increase in the number of engineering students interested in founding spin out businesses to pursue some of their product ideas from their major projects.

Our engineering students interested in careers closer to industrial design now have portfolios of evidence showing their design projects, enabling them to apply to a wider range of design and engineering jobs.

Students benefit from smaller classes and the intensity of multiple teamwork assignments. They get to know each other much more intimately and peer learning is increasing.

The relationships between students and core teaching staff from the intensive units are fulfilling for both students and staff. These lead to more mentoring, more student-centred learning and the development of reflective practice.

Students increase their ability to use creative design methods whilst being able to deploy their core engineering skills for innovation.

Making the changes: learning points

Both top-down support and bottom-up buy-in have been critical to the success of the new program.

Importantly, we were able to create an operating budget that was separate from the other degree programs. This allows us to know exactly how much resource we require to run the program.

The operating budget also included one new academic member of staff, as well as two technicians and funding for external practitioner engagement.

Technician support in the department is a finite resource and led us to design our makerspaces so they could be overseen by the students themselves.

Considerable effort is needed to run the studios including tidying, preparing materials and switching over between intensive units which is more time-consuming than we thought.

All staff teaching D-M-T units are enjoying their creativity and close student engagement. Ensuring that all staff across the departments engage in student projects

for the final year improves the visibility of the course internally, which in turn helps to garner support across the departments.

Studying other institutions through external examining and the initial marketing research has really expanded our ideas around teaching design within an engineering department.

Learnings from running the new program have become part of the department response to a university-wide initiative on curriculum transformation

Student feedback

"I much prefer this degree to straight mechanical engineering... It is closer to my experiences on the placement year and closer to what engineering is going to be in the future..."

"I think the group work is definitely very useful, collaboration is very important and its one of the best things about the course for me."

"I really enjoyed all the coursework modules, even if the workload did occasionally become very heavy! The Mechatronics units were excellent for introducing a more practical side to coding which is proving very useful... The User Centred Design (UCD) unit gave us the opportunity to practise more of the design-based side of the programme and the Design Optimisation unit was great for re-introducing some more technical aspects of engineering back to me."

Key metrics

- The University has been recruiting on the programme since 2016 with the first graduation in 2018/19 and 25-30 students participating each year.
- The female/male mix is 15%/85%.
- 90% of graduates from the programme are employed after 6 months.

Incorporating creativity

University of Birmingham School of Engineering

Programme
Integrated Design Project Suite.

New Approach
Industry-Ready Creative Engineers through
whole-programme Interdisciplinary
Engineering Skill Progression.



About the programme

Engineering at the University of Birmingham offers accredited Masters and Bachelors degree programmes in traditional disciplines such as mechanical, electrical, civil, and cross/minor disciplines such as mechatronics, aerospace and materials. All students study a common first year before specialisation.

Throughout their studies, students undertake Integrated Design Projects in groups. These bring the disciplines together to solve authentic real-world design problems with significant industry input, in addition to the traditional individual capstone projects.

Students are expected to draw on their learning to-date by synthesising learning outcomes across the modularised curriculum.

Recognising that information provision in engineering education is more efficient due to online resource, 60 credits worth of information-provision-oriented modules were removed from programmes to accommodate the Integrated Design Project Suite.

Overview of the new approach

The new approach is focused on incorporating creativity into engineering with the degree of creativity required at each year of the programme explicitly taught.

In the first year, the same general engineering challenge is set for all project groups and there is an expectation that the final design is same for all groups. For example, a miniature prototype bridge that can accept a specified load success is measured by engineering standard.

In the second year, students learn that real problems are more ill-structured and that they have multiple solutions. The challenge is the same for all project groups but contextual factors such as the location in the world and the bridge's function lead groups to produce unique solutions.

Structured creativity tools are introduced – notably IBM Design Thinking tools¹ used by industrial teams, and the TRIZ framework² which codifies creative thinking based on existing patents.

For the third year, challenges vary between groups and are more open-ended. Groups

might be set a problem such as improving logistics in a smart city, where a bridge may or may not be part of the solution.

There is a strong sustainability theme running through the suite which encourages creativity³.

How the programme relates to other New Approaches facets

The programme supports the project work, industry engagement and interdisciplinarity facets of the new approaches:

- Project work: all student group work requires a level of collaboration dependent on the year of study. In the first year, these are general engineering outputs, such as physical prototypes and individual oral and written presentations. For the second year, challenges are more authentic requiring creative design, quantitative simulation and group outputs requiring complex team interactions and recognition of individual disciplines. By the third year, the challenges are fully interdisciplinary with greater consideration of enterprise; groups must simultaneously collaborate and compete.

¹ MBM 2019, Enterprise Design Thinking, IBM, viewed 13 September 2019, www.ibm.com/design/thinking

² Chang, Y.S., Chien, Y.H., Yu, K.C., Chu, Y.H. and Chen, M.Y.C., 2016. Effect of TRIZ on the creativity of engineering students. *Thinking Skills and Creativity*, 19, pp.112-122.

³ Cooke, N.J., Theofanous, M., Saadat, M. and Hawwash, KIM, 2018. Embedding the SDGs into Interdisciplinary Engineering PBL: A Case Study: Structural Mechatronics Integrated Design Project". Proceedings of 46th SEFI Annual Conference in Engineering Education 2018.

- Industry engagement in design and delivery: The project challenges are developed in consultation with industrial stakeholders such as companies and visiting professors. Partners review the challenge to ensure authenticity and deliver guest lectures. The challenges adopt a simplified version the industry-standard stage-gate process to introduce students to the engineering lifecycle.
- Interdisciplinarity: The IDP progression model recognises that students develop a disciplinary identity which is only fully formed by the end of their study.

Leading and managing the change

In 2016, three separate engineering departments: electrical, mechanical and civil, were brought together into a single entity to form a school of engineering. Degree programmes were rationalised, and all students were taught a common first year.

This led to a dilution of disciplinary-specific skill development in the first year as previously taught core knowledge taught in modules were moved into the second year.

The Integrated Design Project Suite was proposed as a mechanism to counteract this. To strengthen disciplinary identities within the school, students would work together on challenges with learning outcomes focussed on interdisciplinary and discipline-specific skills brought to solve real-world problems.

This required collaboration between academics instinctively guarding their own disciplines through fear of change.

These barriers were overcome and change made possible by involving all academic staff in the teaching of the IDP suite: teams of module designers from all disciplines to formulate the projects, drawing on experience from other institutions who had developed similar interdisciplinary initiatives, and utilising all faculty academics in some capacity to support students.

Benefits of the new approach

The Integrated Design Project Suite provides industry-ready students. Many have used their experience to gain industrial placements and graduate positions in companies either directly involved or in related industries.

They learn how their own developing engineering discipline works with others to solve real-world problems and become comfortable in working in high-pressure team-oriented settings.

The university uses the outputs created by students and the showcase events as recruitment materials for new students, and to develop closer links with industrial partners.

Making the changes: learning points

Disciplinary skew is a key issue when bringing together interdisciplinary modules. In line with a national trend, at the University of Birmingham there is an over-abundance of mechanical engineers: the ratio of mechanical to electrical or civil engineers at Birmingham is 4:1.

To mitigate this risk of modules become entrenched in only one discipline, strict demarcation between what constitutes a general engineering conceptual design, and what constitutes a discipline-specific detail design must be made so that teams focus on either one or the other.

For students, working in teams is a stressful experience – doubly so when interdisciplinary where there is further opportunity for misunderstanding.

Therefore, it is important to spend as much resource on providing support structures for managing non-technical group issues as it is to provide resource for technical delivery; assigning an academic to work with each group as a mentor or personal tutor can help alleviate the learning stress.

Student feedback

"The most fulfilling aspect of the project was the freedom to design a real solution to a real engineering problem"

"The best way I can explain why I enjoyed this module so much is that it has been the only module which feels like actually doing engineering, rather than learning about engineering, a frustration I have had with other modules on my course."

"The teamworking nature of [the IDP] strengthened my interpersonal skills an awful lot. I saw benefits of relating, working and behaving selflessly, not for my own gain but for the wider success of my team..."

Key metrics

- The programme has run in this format for four years.
- Every year over 1,000 students from all years participate.
- The female/male ratio is 18%/82%.
- 90% of graduates are in employment after 6 months (95% of all students).



Interdisciplinarity

University of Birmingham School of Engineering

Programme
Digital Innovation Boot-Camp.

New Approach
Training students in cutting-edge digital technologies through research-based evidence and industrial case studies.



About the programme

The Digital Innovation Boot-Camp (DIBC) was organised in collaboration with the academia, industry and the Institution of Engineering and Technology.

It professionally trained students with key skills associated with digital innovations such as virtual reality, augmented reality, blockchain and artificial intelligence. Through this the students were introduced to their application.

Research groups from Universities of Birmingham, Leeds and UCL, and industrial stakeholders from Defence Science and Technology Laboratory, Cosworth and L3T Technologies demonstrated key applications of digital innovations. Towards the end of the week a competition was organised for the students to pitch conceptual solutions to tackling global challenges through digital innovation.

The week-long Digital Innovation Boot-Camp (DIBC) was therefore a vehicle for significant education enhancement within the current academic system, drawing on existing strengths while allowing students direct and comprehensive exposure to research-led educational activities and experience of cutting-edge digital technologies used in different industrial sectors.

Overview of the new approach

The Digital Innovation Boot-Camp was a collaboration between Schools of

Engineering and Business School. It helped encourage creative-thinking around the digital technology agenda, an area which has the scope for a broad base of collaborative research-industry based teaching pathways.

The DIBC tapped into the student's imagination by preparing them for future challenges in a rapidly changing employment/research arena.

An important benefit of the project was the direct engagement in research-intensive teaching and learning which gave inspiration to students around the potential for a career in research and development to at a key stage of their educational journey.

The DIBC enhanced graduate employability by training the students in digital skills and entrepreneurship and the importance of these areas in being work-ready for a career in research or industry.

It also brought a key enhancement to current curricula that embraces the digital technologies (both industry-led and research-driven) and through this the profile of the University's graduates

How the programme relates to other New Approaches facets

Students were involved in the design of the programme through a Pre-Boot Camp workshop, which was used to capture their expectation and their awareness on the digital skills and ensure an inclusive approach.

This was followed by data collection after the Boot Camp via a questionnaire survey to gauge students' enhancements in digital skill.

The students were given the opportunity to put their learning into practice through solving a challenge by using creative-thinking. This reflective learning approach received very positive feedback from the students. Industrial partners appreciated the effectiveness of such an approach.

Leading and managing the change

The programme organisation team comprised of professors, senior lecturers, research fellows and PhD students from a range of backgrounds.

Different research groups and industrial partners were engaged the delivery of the boot-camp which was also supported by the Institution of Engineering and Technology.

The University's Careers Network were involved to guide the students in marketing their digital skills gained during the Boot-Camp to future employers.

Programme funding came from University of Birmingham's Higher Education Future Institute through a competitive bid to the Education Enhancement Fund.

Figure 1 – How familiar are you with the applications of Robotics in your field?

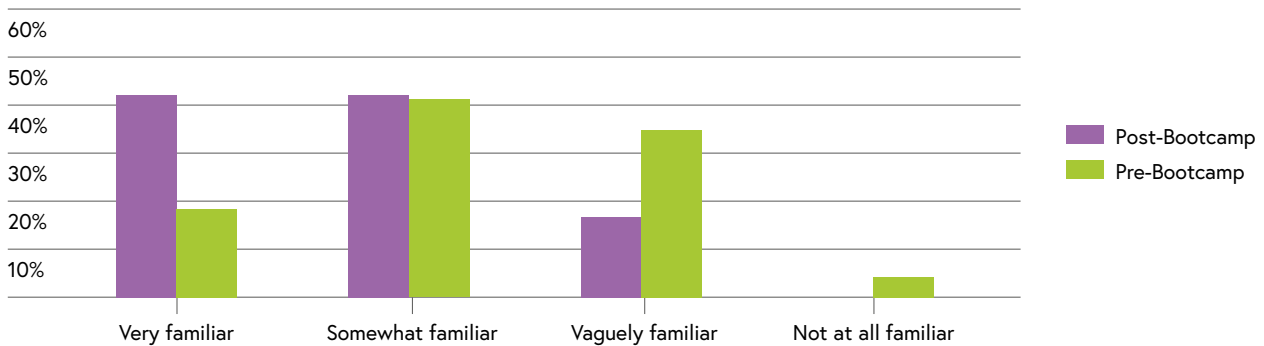
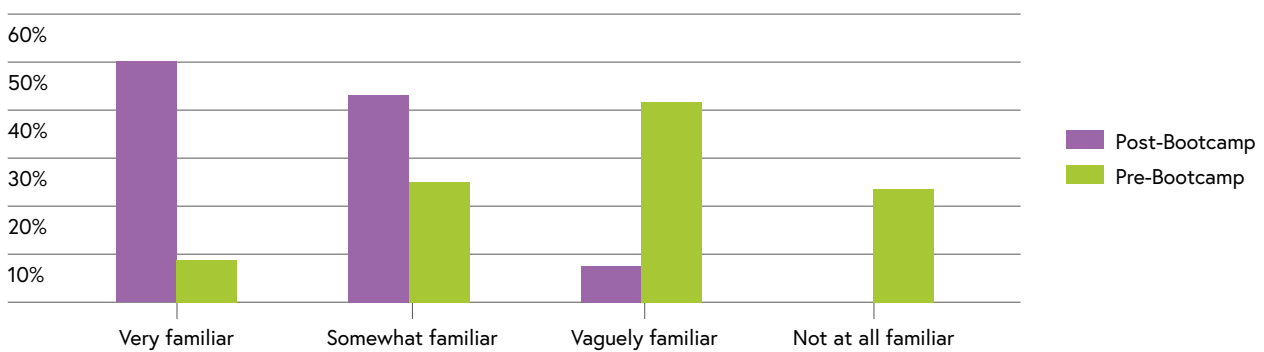


Figure 2 – How familiar are you with the applications of IoT in your field?



Benefits of the new approach

The benefits of the new approach can be summarised as follows:

- Our model of research-based and industry-specific digital skills training is one that can be translated across the university at different levels of learning.
- All students have the opportunity for enhanced professional development.
- Improved graduate employability of the participants by training the students in digital skills and entrepreneurship
- A key enhancement to current curricula that embraces the digital technologies (both industrially-led and research-driven) and through this the profile of our graduates.
- Positioning the University of Birmingham as a forward-looking institution that equips the future generation with up-to-date skills

Making the changes: learning points

While the preparing students for the digital future is necessary and discussed widely^{1,2,3} the challenges have received less attention.

One of the challenges is identifying the skills for the future and catering it within the current curriculum. We found that engaging with industry and having an interdisciplinary approach can help ensure the skills developed are relevant ones. Involving students and capturing their expectations can also help in better design of the programme

Student feedback

"The Boot-camp was an enthralling experience for me as it gave me a taste of different technologies shape the rapidly developing world around us."

Amir Shah, BSc Computer Science

Key metrics

- Two week-long Boot Camps were held in the academic year 2018/9 with 32 students attending.



UNIVERSITY OF BIRMINGHAM

¹ HM Government, (2017), Industrial Strategy: Building a Britain fit for the future. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf
² Munro, M. (2018). "The complicity of digital technologies in the marketisation of UK higher education: exploring the implications of a critical discourse analysis of thirteen national digital teaching and learning strategies." *International Journal of Educational Technology in Higher Education* 15(1): 11.
³ Office for Students, (2018), <https://www.officeforstudents.org.uk/advice-and-guidance/skills-and-employment/digital-skills/>

Incorporating creativity

University of Exeter Department of Engineering

Programme

Embedding project-based learning and entrepreneurship in engineering education.

New Approach

The development of a Gold Standard Project Based Learning (GSPBL) engineering curriculum to improve entrepreneurial competences.



About the programme

This case study focuses on engineering undergraduate curriculum development within the Engineering department of the University of Exeter.

In 2017 the Engineering department embarked upon a review of its programmes and teaching practices.

The review concluded that the new curricula should emphasise collaborative project-based learning (PBL), contextualised teaching and an emphasis on skills development and practical application of knowledge. Embedding entrepreneurship into the new curricula has been central to this approach.

Entrepreneurs and engineers share many common attributes, perhaps the most obvious being that both look to solve problems by identifying deficiencies in the status quo. However, entrepreneurship has historically not featured within the engineering curriculum.

The seeks to equip engineering students with an awareness of entrepreneurship and the skills to pursue entrepreneurial

endeavours as an alternative or compliment to traditional employment upon graduation.

The thread of entrepreneurship runs through the first two years of all engineering programmes with dedicated modules that develop students' skillset and awareness of topics such as rapid product and prototype development, company formation and professional networking.

Overview of the new approach

The initiative used action research for strategic curriculum development. The methodology combines Gold Standard Project Based Learning (GSPBL) [Figure 1]¹ and EntreComp for the creation of a unique engineering curriculum that aims to improve students' entrepreneurial competences.

The initiative consists of the design of a pilot module (Entrepreneurship 1) in the first year of all engineering degree programmes using GSPBL to guide the structure, delivery, PBL and assessment.

The pilot module tested the proposed methodology with Entrepreneurship 1 completed in 2018/2019 before a second module, Entrepreneurship 2, was developed

and is currently being delivered. These new modules are starting to build a new culture of teaching and learning with both staff and students. The EntreComp model was developed as a standard framework for entrepreneurship, identifying the competences that make someone entrepreneurial and therefore supporting entrepreneurial learning [Figure 2]². The main idea behind the initiative is that EntreComp complements GSPBL, creating a progression model which develops entrepreneurial competences from the 1st year module (foundation) to the 2nd year module (intermediate)³.

The authentic industry-linked module included access to Light Detection and Ranging (LiDAR) and Virtual Reality (VR) equipment and lectures on Building Information Modelling (BIM) and entrepreneurship.

The driving question was:
'How can you apply LiDAR scanning technology to create a new product, service or process?'

This open-ended task encourages students to explore, discover and innovate.

¹ PBLWorks. 2019. WHAT: Gold Standard PBL: Essential Project Design Elements. [online] Available at: <https://www.pblworks.org/what-is-pbl/gold-standard-project-design> [Accessed 13 September 2019].

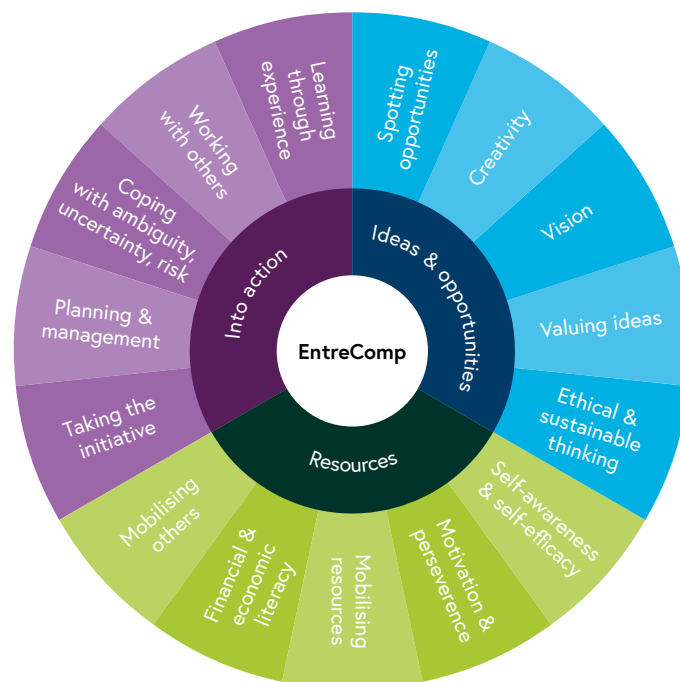
² McCallum, E., Weicht, R., McMullan, L. & Price, A. 2018. EntreComp into Action: get inspired, make it happen. In M. Bacigalupo & W. O'Keefe Eds. *EUR 29105 EN*. Publications Office of the European Union. Luxembourg.

³ Cory, C.Z., Sucala, V.I. & Carroll, S. 2019. *The development of a Gold Standard Project Based Learning (GSPBL) engineering curriculum to improve Entrepreneurial Competence for success in the 4th industrial revolution*. Proceedings of the 47th SEFI Annual Conference - Complexity is the new Normality. Budapest: 16-19 September 2019.

Figure 1 – Gold Standard Project Based Learning



Figure 2 – EntreComp model



How the programme relates to other New Approaches facets

The initiative also relates to the project work and Interdisciplinarity facets of the New Approaches.

GSPBL is central to engineering curriculum development. Over the last 20 years, GSPBL has been developed to integrate and develop essential skills such as communication, collaboration, adaptability, critical thinking, problem solving, technological literacy, creative thinking and self-management during GSPBL projects⁴.

The programme supports interdisciplinarity because of the intrinsic nature of the group projects and of the student teams' outputs. The first major output was a storyboard planning each team's final video. The students presented their work to engineering faculty, academics from the Business School and staff from Business Support.

This cross-disciplinary formative feedback session 'created an exciting atmosphere with authenticity where students were discussing their business ideas directly with staff who had both technical and entrepreneurship experience'³.

The second major output was a 2.5-minute video pitch of the final product, service or process and facilitated the requirement to work towards many of the EntreComp competences.

The students have to introduce and play their video and justify their work through a Q&A with a panel of judges. Peer learning is also facilitated, the students having the opportunity to attend the presentation of at least 8 other teams.

Leading and managing the change

The change has been made possible by a consistent leadership support within the department, a result of the initial review of all engineering programmes undertaken in 2017. The review sought to answer two questions:

- Do existing programmes equip graduates with the skills needed for careers that will extend into the middle of this century?
- Have the existing teaching methodologies evolved with pedagogical and technological advances and students' digital expectations?

The review concluded that despite instances of excellent practice, a department-wide evaluation of what and how is taught was warranted, and significant changes are required. An extensive study followed the review and focused on how an innovative, forward-looking curricula could be developed that equips students with the skills required to thrive in a global engineering industry.

The associated challenges and constraints - namely external requirements set out by the UK accrediting bodies and the pre-existing cultures within the academic and student communities – were also explored and considered.

Based on what we found, a new model of entrepreneurship education of engineering students was developed, consisting of an entrepreneurship initiative pursued independently by the engineering department, supported by the university's innovation and business support team, and by partnerships with entrepreneurship centres based in schools of engineering abroad⁵.

Benefits of the new approach

Engineering students need to develop a thirst for life-long learning and harness their potential with emotional intelligence, creativity, innovation and other 21st century skills.

They need to build their ability to be flexible and adapt to fast changing environments in preparation for the fourth industrial revolution.

The methodology applied to these modules aims to help students to understand and appreciate the benefits of collaboration, linking theory with practice, and entrepreneurship competences with employability.

The reflective reports submitted by the students after their final summative assessment demonstrated that the proposed methodology helps students develop competences in Level 3 and 4 of the EntreComp progression model and empowered them to take risks, make their own choices and take control of their learning experience³.

Student teams were asked to indicate the entrepreneurial competences (EntreComp) they think they most improved as a team during the module. Figure 3 [Figure 3]³ illustrates the students' perception on this matter.

The Research Agenda for the New Discipline of Engineering Education suggests that a transformational change rather than incremental improvements in the way engineering students are recruited and educated is acutely needed in order to be able to confront future challenges. This transformational change must be grounded on 'rigorous research-based approach to our educational system, similar to the way in which research is performed and used in the traditional engineering disciplines'⁶.

⁴ PBLWorks. 2019. *21st Century Skills Table*. Available at: https://my.pblworks.org/system/files/documents/BIE_21stCenturySkills_table_version4.pdf [Accessed 13 September 2019].

⁵ Sucala, V.I., Carroll, S. & Cory, C.Z. 2019. *A new model of entrepreneurship education for engineering students*. Proceedings of the 47th SEFI Annual Conference - Complexity is the new Normality. Budapest: 16-19 September 2019.

Another report – *The global state of the art in engineering education*, argues that practices such as user-centered design, technology-driven entrepreneurship, problem-based learning and a focus on rigor in the engineering fundamentals are common to the current leaders in engineering education⁷.

These publications are highlighting the benefits of embedding entrepreneurship and project-based learning into engineering education.

Figure 3 – Entrepreneurial competences



Spotting opportunities	11%
Creativity	6%
Vision	3%
Valuing ideas	8%
Motivation and perseverance	3%
Financial and economic literacy	3%
Mobilising others	11%
Learning through experience	11%
Working with others	17%
Planning and management	19%
Taking the initiative	3%
Coping with ambiguity, uncertainty, risk	6%

Making the changes: learning points

We believe the key success factors in developing and delivering our programme were:

- A review of the initial status of engineering education from various perspectives (e.g. student satisfaction, employers, academic staff, professional bodies) helps in building the argument and getting the required level of freedom to innovate.
- The support of senior academics within the department and college or faculty. The consistent support and involvement of the department's head is crucial in this endeavour.
- The scarcity of resources, especially of academic time, should be also considered and addressed from the beginning. Failure to do so will jeopardise the change process and will diminish academics enthusiasm very soon.
- Considering carefully how the introduction of new elements are related to the accrediting bodies requirements are also very important from the very beginning. Active engagement with these bodies could be a way to deal with the potential risks associated.

An initial pilot might be a convincing way of gathering more support among both academics and students.

Student feedback

"By doing stuff like this it really brings it to life, (...) but when you get to put on the goggles and the VR stuff it really opens your eyes to what you can use it for and it kind of blows your mind a little bit for the potential of what you can do with it, so for me it was amazing."

"Hands on experience is that link between the theory and the actual application of what you have learnt, so the two combined allows you to have the necessary skills to enter the workforce."

Statistics

- The programme has run for one year with 220 student participants.

⁶ The Research Agenda for the New Discipline of Engineering Education. 2013. *Journal of Engineering Education*. Vol. 95. Issue 4.
⁷ Graham, R. 2018. *The global state of the art in engineering education*. Cambridge, MA: Massachusetts Institute of Technology.

Workplace experience

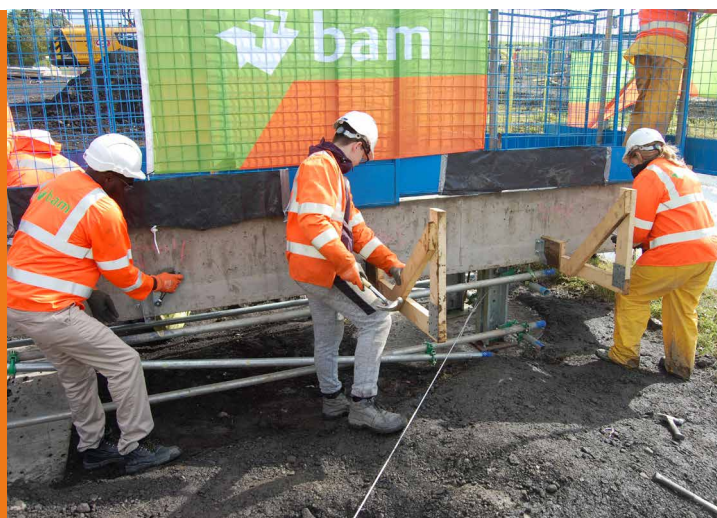
University of Strathclyde Department of Civil & Environmental Engineering

Programme

Civil Engineering 4 Real (CE4R): co-curricular learning for undergraduate 2012-2019.

New Approach

CE4R comprises voluntary evening workshops facilitated by practicing engineers where students use authentic documentation and collaborate in peer learning to solve industrial problems creating classroom values that resemble workplace values through experience-led learning.



About the programme

Vocational disciplines such as engineering provide an ideal opportunity for contextualising the curriculum.

The provision of co-curricular activities can stimulate students to assimilate their prior knowledge and skills whilst enhancing employability attributes. Team-based co-curricular activities linked to problem-based learning can offer students a quasi-authentic experience of engineering practice.

This case study provides evidence of a successful co-curricular initiative supported by local civil engineering employers that could be benchmarked by any vocational discipline in higher education institutions. Civil Engineering 4 Real (CE4R)¹ are evening workshops facilitated by practicing engineers, where student attendance

is voluntary. Students use authentic documentation and collaborate in peer learning to solve industrial problems creating classroom values that resemble workplace values through experience-led learning².

CE4R has assisted student's anticipatory socialisation into their disciplinary profession. The initiative has received plaudits from course validation and accreditation panels and has been specifically named and commended in the free-text comments section of the annual National Student Survey (NSS).

Overview of the new approach

Over the past three decades there has been a growth in the adoption of constructivist pedagogy in higher education (particularly in vocational disciplines)

given its promotion of active learning and practical experiences linking theory to professional practice. An authentic curriculum that contextualises learning and assist students to develop a professional identity.

Within the engineering sector, a number of commentators have argued that these professional skills are best nurtured through closer industry-academia collaboration^{3,4}.

Through the provision of real engineering documentation, students are encouraged to integrate theory with context to experience – as far as possible – working as an engineer and developing an engineering identity.

Research has stressed the importance of the inclusion of real-life engineers in such initiatives⁵ and so, was pivotal for the authenticity of the CE4R workshops.

¹ Murray, M., Hendry, G., & McQuade, R. (2019). Civil Engineering 4 Real (CE4R): Co-curricular Learning for Undergraduates. *European Journal of Engineering Education*. (Published Online @ <https://doi.org/10.1080/03043797.2019.1585762>)

² Broadbent, O. & McCann, E. (2016). Experience-led learning for engineers: A good practice guide. Royal Academy of Engineering. Retrieved 10th September 2019, from: <http://www.raeng.org.uk/publications/reports/experience-led-learning-for-engineers>.

³ Edward, N. S., and C. R. Middleton. (2001). "Occupational Socialisation: A New Model of the Engineer's Formation." Paper presented at 2001 International Conference on Engineering Education, Oslo, Norway. <http://www.ineer.org/Events/ICEE2001/Proceedings/papers/257.pdf>.

⁴ Royal Academy of Engineering. (2007). *Educating Engineers for the 21st Century*. London: Royal Academy of Engineering. Accessed January 11, 2019. http://www.raeng.org.uk/news/publications/list/reports/Educating_Engineers_21st_Century.pdf.

⁵ Wankat, P. C., and F. S. Oreovicz. (2015). *Teaching Engineering*. 2nd ed. West Lafayette, IN: Purdue University Press.

How the programme relates to other New Approaches facets

Whilst CE4R cannot replicate the nuanced workplace environment that students can experience (vis-à-vis sandwich courses and vacation employment) in disciplinary employment, the workshops do provide a highly authentic workplace experience within the classroom.

Students engage and are enthused by authentic and relevant engineering experiences⁶ and the topics covered in the workshops provided the students with a wide range of sub-disciplinary knowledge and exposed them to the professional identities.

During the 2018-19 session one of the workshops sought to provide an interdisciplinary experience with students from the mechanical and electrical departments being invited to attend a workshop based on a Network Rail contract.

Feedback from the students indicated that there is strong appetite to engage in more interdisciplinary group activities.

"Pleased I took part and I learned a few things about industry problem solving. Would definitely take part again. Really good to meet different disciplines to gain a new perspective."

"It was a wonderful experience to cooperate with such nice engineers from another department."

Leading and managing the change

The initiative was conceived and implemented by the case study author with industry support.

The co-curricular nature of CE4R has externalised evidence of leadership with industry rather than within academia.

The author's motive and inspiration to label the workshop series as CE4R arose from



a mix of latent contemplation (as a desire to expose students to industrial practice through authentic pedagogy) and emergent thinking encapsulated through involuntary daydreaming and an early morning awakening from sleep (an 'epiphany') in 2012.

As such, the conception of CE4R as both brand and logo are the result of an intertwining of the author's ontological and epistemological beliefs regarding the deployment of teaching and learning in engineering education.

Benefits of the new approach

The University of Strathclyde prides itself as being "A Place of Useful learning".

Whilst the establishment of strong links with industry is typically associated with research and knowledge exchange partnerships, CE4R demonstrates the contribution that industry can have to

enhancing the student experience and to developing work-ready graduates who are engaged, enterprising, enquiring, and ethically, globally and culturally aware.

CE4R has contributed to a recognition by the QAA Scotland: Enhancement-led Institutional Review 2019⁷.

The university has a close relationship with industry which is deeply embedded in the activities of the institution and the student learning experience. For students, the anonymous feedback collected after each workshop and further unsolicited feedback prove the value of the initiative:

"I'd like to take the chance to thank you for hosting CE4R throughout my time at university. I know I would not have been successful in my search for placements and a grad job if I hadn't had the CE4R experience to discuss in my interviews and application."

⁶ Engineering Professors Council. (2018). "New Approaches to Engineering HE: The Six Facets." Accessed July 1, 2019. <http://epc.ac.uk/new-approaches-to-engineering-he-the-six-facets/>.

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Making the changes: learning points

Building a rapport with local industry starts at home with your existing students and in this way initiates such as CE4R become self-priming once the students become graduates.

CE4R is a win-win for employers, employees, students and universities seeking to enhance the employability of engineering graduates.

Recruiting presenters for the CE4R workshops benefited from an existing portfolio of employers who were already supporting a mentoring initiative⁸ and this allowed further value to be gained from established partnerships.

However, it is important to maintain such relationships and issues such as passion, trust and value alignment contribute to successful collaborations.

As the industry contribution to CE4R is "time in kind" it is pertinent to consider how often employers are approached for assistance, but some employers have been open to further collaboration through engagement with Knowledge Exchange Partnerships and the Graduate Apprenticeship (Degree Apprenticeships) bids for funding.

Awarding students a 2hrs CPD certificate for participation in a CE4R workshop has been pivotal in disseminating the initiative to employers, as students have recorded their participation on their CV's and blogs and have spoken about their attendance during recruitment interviews as evidenced below:



⁷ QAA Scotland: Enhancement-led Institutional Review of University of Strathclyde Technical Report, March 2019, https://www.qaa.ac.uk/docs/qaa/reports/university-of-strathclyde-elir-outcome-19.pdf?sfvrsn=8678c481_4

⁸ Murray, M., A. Ross, N. Blaney, and L. Adamson. (2015). "Mentoring Undergraduate Civil Engineering Students." *Proceedings of the ICE-Management, Procurement & Law* 168 (4): 189–198.



"The CE4R workshops were invaluable at my assessment centre yesterday with WSP, as the group exercise was very similar to how I solve problems during CE4R.

I received a phone call this afternoon saying that they wanted to hire me, and they particularly liked how I worked within the group to solve the exercise.

They positively praised how I presented knowledge to other potential candidates during the task without forcing ideas upon everyone and how I tried to get the whole group involved. Without CE4R workshops I feel I would have struggled with the group exercise."

(Unsolicited email from MEng graduating student, 2015).

Student feedback

"The workshop helped get away from the calculation side of things, which can be a bit dull. It helped reinforce that idea of team work to real life problems, rather than applied mathematics. It basically helps highlight how exciting Civil Engineering can be, every problem is different and has to be approached differently!"

"It's great to see that no matter how diverse the university backgrounds are of the participants, first years and fifth years can think on the same wavelength, showing how we are all developing our Civil Engineering way of thinking."

Key metrics

- CE4R has run for seven years with a total of 80 two-hour workshops delivered.
- 434 undergraduate students have attended one or more workshops and we have generated 3,834 hours of CPD.
- We have worked with 54 industrial partners (25 contractors / 24 consultants / 5 clients) and 156 industry workshop presenters, including alumni.
- Female-male balance of 35%-65%.



Industry engagement

University of Sheffield Department of Automatic Control and Systems Engineering

Programme

Industrial Automation and Industry 4.0 Teaching.

New Approach

Cyber-Physical Production Systems (CPPS) Industrial Automation and Industry 4.0 Laboratory.



About the programme

The programme is an MSc in Advanced Control and the module is called Industrial Automation which uses a Cyber Physical laboratory as multi-use case study.

The CPPS Lab is a modular Industry 4.0 learning system and representative of a modern industrial production line. It is fitted with the capabilities to demonstrate and communicate with Industry 4.0 methodologies and standards. Fully supported by Siemens and Festo, the hardware and software uses their latest technology, providing students with the most appropriate training to transition into industry.

The platform is used for undergraduate and postgraduate individual and group projects as well as final year individual projects. The laboratory provides an enhanced platform to put into practise the skills gained in the new Industrial Automation masters level module.

The students can work on a real-world industrial system prior to leaving the university in a safe learning environment.

Overview of the new approach

The Cyber-Physical Production System Industrial Automation and Industry 4.0 Laboratory is fully support by Siemens UK.

The laboratory is situated in the MindSphere lounge which is a Cloud and Industry 4.0 supported infrastructure within the university.

The combined system forms part of the Connected Curriculum sponsored by Siemens.

Though this industrial engagement the students learn the latest industry standards and technologies, using real-world industrial hardware and software.

The collaboration enables case studies, real-life problem solving and hands-on learning with the ultimate goal to minimise the knowledge gap between leaving university and embarking on a career in industry.

This is done through the use of very advanced and specific equipment such as the CPPS in teaching which is challenging to simulate and replicate.

The students are introduced to the subject in the year three group design project and then they continue to use the equipment for more advanced topics and research in their final year individual projects.

This is a perfect case study for the MSc Industrial Automation module giving the students the opportunity to work with an industrial standard system and help them in their future career.

How the programme relates to other New Approaches facets

The laboratory enables project work to be conducted across academic disciplines. It is managed by the Automatic Control and Systems Engineering department (ACSE) which by its nature is a vastly multidisciplinary department. The University of Sheffield Mechanical and Chemical and Biological departments are also intending to use the lab as a case study for their teaching.

Project work can be carried out in control systems, machine learning, AI, cyber-security, predictive maintenance, communications, process optimisation, manufacturing intelligence, digital twins and much more.

This programme provides a novel approach to teaching which is fully supported by a strong industrial engagement in design and delivery.

There are many current projects and research being undertaken on the CPPS in which Siemens and Festo are integral with the support.

This shows the students the relevance of teaching material to the actual systems that are currently using in industry to enhance their employability skills. In addition, we are working closely with local SMEs in Sheffield to do some research on the system which is relevant to local manufacturers.

Leading and managing the change

The rise of industry 4.0 technologies and digitisation of manufacturing in industry requires universities to ensure that when students graduate, they are ready for these challenges.

The university has employed new staff and invested in new teaching laboratories to support the teaching of industrial automation.

The department invested approximately £300,000 to develop a complete Industrial Automation lab which includes the latest version of Siemens 1500 PLCs and human industrial interfaces.

As the CPPS lab is an advanced tool, the university has ensured there is a pre-course requirement to undertake independent study and research.

This helps the students to learn control programming and monitoring before they aim to work and do projects with our CPPS advanced system.

This module and the associated case studies are not restricted to the control department and courses are cross-departmental. For example, the Mechanical Engineering department plans for its students to take part in the module and use CPPS as a working case study.

Benefits of the new approach

The key benefit is that students hit the ground running when they start their first job in industry.

By introducing collaborative project work and closing the gap between academic theory and the practicalities of industrial practise, student employability is improved. Hands-on practical classes also result in better student satisfaction scores which means the class fits the ethos of improving teaching standards within the Teaching Education Framework.

A further benefit to the university and students is that the academics and university teachers understand the latest industrial practises and so they can teach courses where the content is reflects emerging technologies and innovations. Finally, by working closely with significant industrial partners such as Siemens and Festo, university staff have the opportunity to do more research and apply for more funding, which also benefits the university.

Making the changes: learning points

Universities need to be up-to-date with the cutting-edge technologies used by industry to ensure students graduate with the right standard of knowledge they need to be successful in future employment. This improves the university reputation and increases student satisfaction by giving them experience of the highly advanced systems used in industry.

It isn't just important to use advanced equipment and teaching methods such as the CPPS: lecturers must also find the best way of teaching and preparing the material for the students.

We found that a group project was the best way to start using this new approach to learning because it helped students develop an understanding of the different aspects of the equipment and technology.

For final year individual students projects we defined new small projects on the current system and tried to solve them.

Finally, a new module can be developed according to the equipment not only using that as a case study but also start using it as programming and monitoring manufacturing systems.



Student feedback

As this is new equipment which has only been used for a year with students working in a group, we only have feedback at this stage. They tell us that although it is very challenging future industrial system to work with, they can see it will be very useful for their future career.

Key metrics

- The CPPS lab has been used for group, individual and research projects for one year.
- A total of 90 students take the Industrial Automation module – this will grow as other lecturers use the kit for their modules.



The
University
Of
Sheffield.

Incorporating creativity

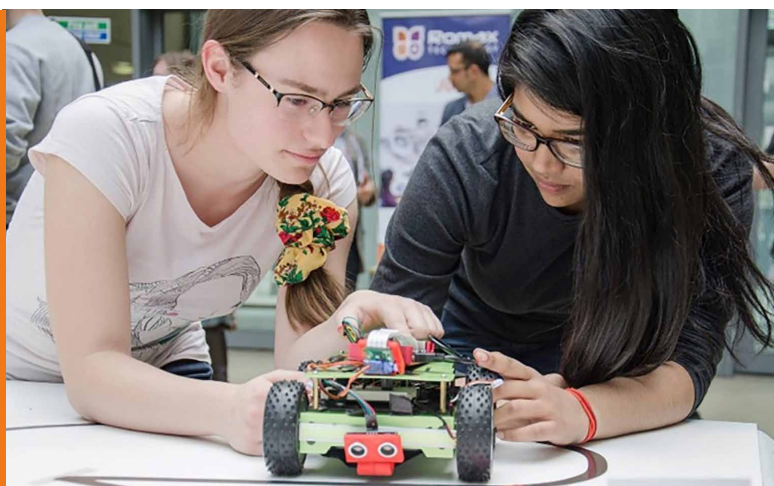
University of Nottingham Department of Electrical and Electronic Engineering

Programme

Applied Electrical & Electronic Engineering Design.

New Approach

The new approach for Nottingham sees the incorporation of a significant element, one third of the academic year, of Project Based Learning (PBL) within the first-year curriculum of the Electrical and Electronic Engineering degree courses.



About the programme

All undergraduate students in the Department of Electrical and Electronic Engineering follow a common programme of study for the first two years, allowing them to change to a different plan up until the end of their second year.

These first two years cover all of the fundamentals of electrical and electronic engineering.

Project work is an important aspect of our engineering degrees and this forms a significant thread throughout all of our plans.

In years one and two students, work on group projects during several week-long project laboratories allowing students to put into practice the material covered in lectures.

In the final years of study, students undertake a mix of compulsory and optional specialist modules, dependent upon their chosen discipline.

In the penultimate year of study on the four-year programme students undertake a significant industry led group project and all students in their final year of study undertake an individual project, supervised by a member of academic staff.

Overview of the new approach

The changes made were motivated by a desire to include a greater amount of small-group, practical lab-based activity that would support the pedagogical requirements of project-based learning.

Traditionally, practical laboratory exercises found within the electrical and electronic engineering programme have been short, guided experiments that lacked significant elements of design and/or problem solving.

The new approach reduced the requirement for short, guided exercises while encompassing all the required learning outcomes within a series of seven full-week sessions spread throughout the academic year.

The first of these sessions is timetabled for the second teaching week, engaging the students very early in their academic career, and setting the tone for the course as a whole. It inspires the students, builds confidence and encourages them to begin to think as engineers from the outset.

This first session also builds up the basic set of practical skills that would be required for the subsequent sessions and develops a positive attitude to team working within a professional environment.

How the programme relates to other New Approaches facets

The department's Industrial Advisory Board gave input to the proposed changes from the outset.

Industrial representatives and our associated professional body, the Institution of Engineering Technology (IET), are brought into the project activities to further support the development of team working skills and discuss mentoring from the outset, through bespoke workshop activities that fall between the full week laboratory-based sessions.

These industrial representatives also act as judges in the final evaluation of the solutions developed by the students.

Leading and managing the change

In recognition of the changing higher education landscape, the Department of Electrical and Electronic Engineering undertook a radical course review.

This was overseen by a management group of senior academics and led by a small, core team of more junior academics who were tasked to radically change the way the first-year course is delivered, taught and supported.

Central to the success of this was the requirement for a substantial project-based learning module that would contribute to developing the essential core skills of our undergraduate students required by industry that would: enhance team working; develop approaches to problem solving; develop an engineering way of thinking and ultimately enhance their employability.

Whereas traditional engineering labs maybe be overseen by an academic and supported by research students who have been trained as demonstrators, a more substantial system of support was required with significant contributions required from both academic staff and technical teams on the ground during the project sessions.

Considerable attention was paid to this and as a result the current teaching and support team now encompasses one lead academic, a further three academics, three teaching assistants and contributions from three engineering technicians.



Benefits of the new approach

The primary aim was to enable our students, from the outset, to think and work as engineers.

Within the formal framework of the module (encompassing all the learning objectives for the module), time was allocated for the inclusion of additional activities developed by the academics supporting the module.

The key goal of these additional activities was to add an element of fun, while

positively promoting a sense of community within the student cohort.

This has been successfully achieved through ad-hoc design tasks, problem-solving and competition-driven challenges. As the weeks progress, the design challenges include an increasing opportunity for creative thinking, allowing groups to better demonstrate their full range of abilities.

However, there are always several paths to achieve the same outcome, some more technically challenging than others.

This provides groups of all abilities a realistic chance of reaching the aims/objectives of that particular week's design challenge.

This problem-solving approach, implemented and supported by the dedicated team, has been recognised formally by our students, external examiners, our IET accreditation panel and industrial partners as providing a pivotal role in the transition of students from FE to HE and ultimately to professional engineers. The impact of this transition period should not be underestimated: how individual students react could negatively impact team dynamics. The early stages of the module were therefore designed to lead the students quickly through individual problem solving, working as a group and competing as a team so as to build confidence early on.

Making the changes: learning points

The development of this module was only possible through significant changes to the whole curriculum.

Day-to-day management of the module requires a significant staffing investment to ensure the necessary level of support is provided within the practical sessions. Staff must approach this support with the mindset of encouraging the students to think through the problems they face rather than showing them the solution.

Following the first year of implementation it was clear that an off-the-shelf hardware platform could not suitably support the planned activities and significant effort was spent in the design and production of a bespoke platform, which has now been successfully implemented.

Student feedback

"I really enjoy the module and putting theory into practise: it tests my skills and helps improve them further."

"Good opportunity to apply knowledge gained throughout the course. Some groups felt imbalanced, leading to frustration. Difficulties arose when some group members lacked knowledge, confidence or enthusiasm to contribute in tasks, meaning such groups didn't progress as far as others. Overall an excellent experience. Even the difficulties would aid in professional development and team work skills."

Statistics

- Programme has run in this format for three years for a total of 300 students.
- Gender balance: 14% female in 2016/17; 18% in 17/18; 19% in 18/19.



Workplace experience

University of Warwick Warwick Manufacturing Group

Programme

Quality Methods and Advanced Quality Techniques Education Modules on the BEng (Hons) Applied Engineering Programme at WMG.

New Approach

Work-based learning for degree apprentices.



About the programme

Degree apprentices on the BEng (Hons) Applied Engineering Programme at WMG, are employed by industry and study a range of topics/modules as a holistic degree as part-time students on block release over four years.

Apprentices learn six themes during the first two years:

- Mathematical techniques
- Mechanical processes
- Electrical principles
- Materials science
- Design
- Industrial Management

The programme benefits from addressing challenges faced by employers with skills that are essential for the next generation of engineers^{1,2}. This case study focuses on the latter.

During year one, the apprentice learns the fundamentals of industrial management and operations. In year two (the basis for this case study) the principles of statistics, and essential tools for statistical improvement

in manufacturing and service operations: Statistical Process Control.

In year three apprentices advance to a one-week module in Advanced Quality Techniques, where concepts such as Six Sigma are taught as well as more strategic elements.

Degree apprentices are expected to take on an extended project (dissertation) addressing a 'real industrial need' in both the third and fourth years of the programme.

The projects, by definition of being part of an apprenticeship, should address a real-time requirement from industry. This proposal demonstrates results by way of demonstrable payback for the sponsoring organisation for their investment in the programme.

Overview of the new approach

The methodology in the programme is based on the idea that the teaching of strategic improvement concepts too early is unlikely to result in any demonstrable benefits for the host organisation of the apprentice.

It reflects the fact that in annual reviews the university will typically provide examples of how the apprenticeship has benefited the host organisation.

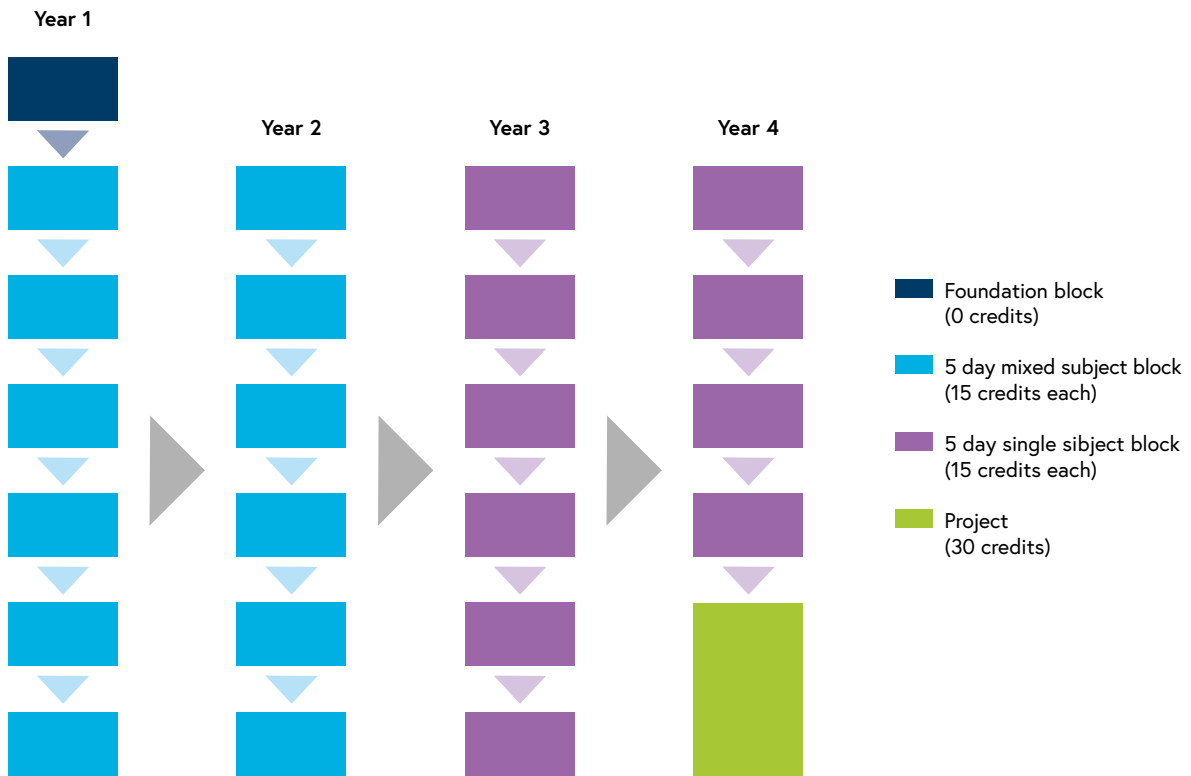
Although it is useful for the apprentice to be knowledgeable of strategic aspects, the new approach which outlined here is focused on fundamental concepts and knowledge which can deliver better benefits to the employer early in the apprenticeship.

The apprentice can build on this to further their improvement initiatives and potentially build a directed strategic platform, which would employ the later education in their programme.

¹ Engineering UK 2018: The state of Engineering, Engineering UK. Accessible at <https://www.engineeringuk.com/media/156187/state-of-engineering-report-2018.pdf>

² Experience Enhanced: Improving Engineering Degree Apprenticeships, 2018, Engineering Professors Council Accessible at <http://epc.ac.uk/wp-content/uploads/2018/09/Experience-enhanced.pdf>

Figure 1 – AEP Structure



How the programme relates to other New Approaches facets

Most of the apprentices' time will be spent in the workplace at the sponsoring organisation, with either day- or block-release to the university.

The learning of quality management principles is greatly enhanced when the apprentice has an opportunity to make a real-life change in their organisation.

The teaching of quality in many institutes is at the strategic level, as such, apprentices are unlikely to be able to enact any demonstrable real change from their learning.

By teaching statistical fundamentals, building on those which learn the tools and techniques for quality improvement (in year two of the degree programme), the apprentice is equipped with a toolkit that enables them to deliver measureable and quantifiable benefits to their employer in the workplace.

These can be demonstrated both by cost savings as a result of the improvement for the organisation and intangible benefits such as better working practises.

An example of the improvements, in terms of cost benefit, made by a year-three degree apprentice is highlighted in the student feedback section which follows.

Leading and managing the change

The programme currently has degree apprentices from large manufacturing organisations, such as Jaguar Land Rover, Rolls Royce, GSK and Airbus and Aston Martin as well as smaller local manufacturing companies. As of 2019, there were 17 companies sponsoring degree apprentices on the programme.

The nature of the programme allows for these organisations to benefit from the degree apprenticeship being tailored (in the final two years of the degree programme) to develop apprentices for a long-term career.

Figure 2 – JH CBA

Project	Cost					Benefit				
	Average time spent per week (hours)	Average hourly cost of	Number of engineers	Cost per week	Actual cost (6 months)	Average number of issues per week	Rectification time (hours)	Hourly labour cost (£)	Cost per week	Actual savings in 6 months
IMC	2	£15.00	2	£60.00	£1,440.00	14	1.5	£15.00	£315.00	£7,560.00
BCM	2	£15.00	3	£90.00	£2,160.00	11	1.5	£15.00	£247.50	£5,940.00
Total £3,600.00					Total £13,500.00					
Overall evaluation = £9,900.00 savings										

The programme team maintains a close relationship with employers to ensure that the content of the course is relevant and current.

A dedicated staff member from the university is based at the employer organisation to manage the degree apprentice's journey and to ensure progression through the programme.

These relationships not only help the apprentices identify potential training opportunities, but find suitable work-based projects which can be used for the academic credit.

The close relationship between the HE provider and the employers have also helped to develop newer degree apprenticeship offerings (such as the BEng (Hons) Digital Technology Solutions) which addresses the new challenges of digital manufacturing.

Benefits of the new approach

Students attain higher marks when their project work is directly related to an industrial problem. For degree apprentices, this is part of their programme.

Typically, the employer will engage the degree apprentice in a final year project that addresses a real-life industrial problem. In this case, the problems that the degree apprentice seeks to solve are directly related to their current role in their organisation. As such, a strategic project is unlikely to result in any short-term significant improvement.

By teaching the fundamental principles of statistics and the toolsets of quality improvement that employ such mathematical techniques, the degree apprentice is able to quantify the current process and then to target areas for improvement.

Once the new process has been implemented, the degree apprentice can compare the new state with the previous and quantify the benefits.



A recent article³ reports that there is little 'understanding of the benefit of an apprenticeship' by those that apply for the scheme, this equally applies to the host employers who may not (yet) realise the potential return on their investment to this scheme.

This gives the employer an immediate benefit gained from engaging in the degree apprenticeship and the apprentice themselves are recognised for their contribution to their workplace and advance in their career.

³ Apprenticeships Make the Grade – Chartered Management Institute. Aug 2019. Accessible at: <https://www.managers.org.uk/about-us/media-centre/cmi-press-releases/apprenticeships-make-the-grade>

Making the changes: learning points

In this subject field (Engineering Quality Improvement), many lecturers can fall into the trap of adopting a standard textbook and delivering a series of lectures on this subject.

These topics may cover elements such as, 'Just-In-Time', 'Total Quality Management' and 'World Class Manufacturing'. Whilst they are important for a graduate engineer, it may take some time before the graduate engineer is in a suitably senior position to be able to be given responsibility for a strategic project.

Our New Approach demonstrates the benefits of delivering these topics at the right time.

Where these concepts are introduced too early, the apprentice is not at the level of seniority to lead projects to enact such changes at their employer organisation. Our experience is that it may be more effective to teach the core principles of statistics and statistical improvement tools so that the apprentice is able to employ these 'skills' straight away and demonstrate their benefit.

Teaching core principles of statistics is challenging, however, lecturers should be encouraged not to squeeze in an 'entire statistics degree' in a few lectures (or module), rather, the elements needed for the student/apprentice to be able to learn the SPC tools.

The lecturer should demonstrate that by learning the root principles (using real life examples during lectures and seminars) then the student/apprentice will feel equipped to make these changes during the apprenticeship and be recognised/rewarded for the resultant improvements.



Student feedback

"My project on the effectiveness of Six Sigma was an eye-opener to the senior management team in Jaguar Land Rover. There were numerous projects in JLR where a team or individual would follow Six Sigma methodology blindly without considering its effectiveness.

On the AEP programme, I studied two modules directly impacting and influencing my project: Quality Methodology & Advanced Quality Techniques.

QM introduced to me a number of quality methodologies and the fundamentals surrounding them, whereas AQT went further into the application of these quality methodologies.

These modules guided me to think critically and evaluate methodologies rather than just following it blindly. This resulted in the identification of process improvements, which demonstrated a quantifiable (significant) cost saving for the company."

Jawad Halim, Y4 Degree Apprentice.

Key metrics

- The programme has run in its current format since 2013.
- Two cohorts of 70 run in parallel, with 140 students per year in each of the 4 years of the programme.
- Female-to-male student ratio: 11%-89% as of 2019.
- The AEP has 'sponsored' students (non-degree apprentices) who are typically older than degree apprentices. These participants are frequently the first in their family to engage in higher education.

Interdisciplinarity

University of Warwick Warwick Manufacturing Group

Programme

Creativity in Interdisciplinary Designed Learning:
Building a Learning Community for Tomorrow.

New Approach

The Creativity in Interdisciplinary Designed Learning approach builds on experience, theory, practice and research to provide the building blocks for a completely new direction in engineering education within WMG.



About the programme

The Creativity in IDL programme of change management in engineering education is grounded in the Relationships, Variety and Synergy (RVS) model of engineering education published by Clark & Andrews (2014)¹ in which three key concepts were introduced as the basis of future-facing engineering education.

These three concepts focus around:

- Academic and professional relationships
- Variety in learning and teaching pedagogy and flexibility in practice
- Synergy across and within the curriculum encapsulating students' emerging epistemologies and prior learning whilst incorporating industrial and professional body perspectives

The newly designed change management strategy advances the ideas contained in the RVS model to incorporate the

professional practitioner approach which were presented at the first New Approaches to Engineering Higher Education Conference by Clark and Andrews (2017)².

It also builds on the work conducted by the UK & Ireland Engineering Education Research Network under the auspices of the Engineering Edge Project (2019)³.

Aimed at building a learning community for tomorrow, in which academic colleagues from a range of engineering and other disciplines work together with engineers from a range of subject areas and other professionals, the strategy introduced a series of innovative pedagogies and practices to the classroom in WMG, University of Warwick⁴. This is a large engineering department which currently has around 1,200 postgraduate and 400 undergraduate students enrolled on a range of courses including full time and degree apprenticeships.

Overview of the new approach

Embodying a co-constructive approach to change in which colleagues are supported through two distinctive levels of professional development within teaching and students are engaged as partners in learning. The vision for change has five distinctive aims:

- Deliver the highest quality education in our respective fields to WMG and, where appropriate, University of Warwick engineering students.
- Provide education that is relevant, engaging and adds value for students so they can realise their aspirations within WMG and beyond, in their chosen careers.
- Develop and disseminate a model of education that is globally recognised for its quality and innovation.

¹ Clark, R. & Andrews, J. (2014). Relationships, Variety & Synergy [RVS]: The Vital Ingredients for Scholarship in Engineering Education? A Case-Study. *European Journal of Engineering Education*. 39. 6. pp 585-600

² Clark, R. & Andrews, J. (2017). "Engineering' or 'The Engineer'? A paradox of professionalism". *New Approaches to Engineering Education*. pp 51-58. London. Institute of Engineering & Technology; The Engineering Professor's Council. <http://epc.ac.uk/wp-content/uploads/2017/06/New-Approaches-Conference-Proceedings-book-final.pdf>

³ Knowles, G., Clark, R. & Andrews, J. (2019) Herding Cats? Innovation and Change Management in Engineering Education. SEFI Annual Conference. Budapest. September 2019

⁴ Clark, R., Penlington, R., Andrews, J. & Knowles, K. (2019) Fit for Purpose? Engineering Educators', Teacher Training & Engineering Scholarship. SEFI Annual Conference. Budapest. September 2019.

- Underpin all engineering education with high levels of scholarship and research.
- Create and deliver engineering education which features inspiring teaching and within world-class learning spaces.

To deliver these aims the Creativity in IDL programme focuses on five different areas of WMG's core activities:

- **Courses:** From the summer of 2019 all WMG courses were subject to an ongoing redesign process. This involved increased levels of embedded industrial collaboration in which academic quality assurance and enhancement are aligned with student employability and professionalism. Additionally, closer alignment between undergraduate and postgraduate courses made for a more coherent approach to programme design.
- **Student Experience:** WMG is developing, trialling and implementing initiatives which promote overall student experience. This includes:
 - The appointment of academic leads for undergraduate and postgraduate student experience
 - A concerted effort to better train and support individual personal tutors and academic teaching staff.
 - Student focus groups which provide ongoing evidence of where students' needs are being met and where more work needs to be done.
 - Creating alternatives to traditional classroom learning which are developed and tested by a team of educational innovators, developers and researchers from the Education Innovation Group (EIG) who work closely with colleagues in all teaching areas.
- **Learning and Teaching:** The EIG launched at the beginning of 2019 and has the specific remit of promoting high quality learning and teaching through the implementation of empirically grounded innovative pedagogies and practice.

- **Staff:** A new WMG specific Professional Pathway Programme supports all teaching-focused colleagues. Excellence in teaching is recognised, celebrated and rewarded.
- **Leadership:** A recent change of leadership in education has seen the importance placed on learning and teaching increase in terms of internal kudos; whilst a clear educational strategy is being enacted in which key performance indicators are being constructed and acted upon.

To summarise, a wind of change is sweeping through the department in which innovative technologies, teaching and student support are combined to provide an educational learning community that is both responsive to industry and academically sound.

How the programme relates to other New Approaches facets

The programme embodies all five facets of the New Approaches programme, with creativity and interdisciplinarity forming the mainstay of the change.

Student diversity is increasing through the development of innovative degree apprenticeship programmes where industry and academics collaborate to ensure there are equal opportunities. At the postgraduate level, scholarships are offered to UK and EU students from lower socio-economic groups. All programmes are open to overseas students.

WMG's main strength is in its industrial contacts and partnerships. Building on this strength, a large team of professionals works closely with WMG colleagues to assure the relevance and academic validity of learning and teaching. Such external colleagues play an important role on the postgraduate programmes in ensuring the relevance and connections are highlighted and reinforced.

Most undergraduate students within the department are employed in industry. Each programme has signature pedagogies to ensure they are relevant to industry, academically valid and linked to professional practice. At postgraduate level, industrial projects add a level of realism and work-based learning on apprenticeships gives graduates a distinctive edge and ensures workplace impact whilst adding quality and uniqueness to all of the programmes.

All education and research within the department is conducted across disciplines, with engineers, project managers, quality managers, computer scientists, mathematicians and many other disciplines working together to provide a distinctive range of industrially relevant courses.

Leading and managing the change

The process of change began a little over two years ago.

More recently, a newly appointed Director of Education is working at Executive level to conceptualise and facilitate an ongoing change management strategy.

This year an intensive internal review is taking place across all taught programmes. This is being followed up by numerous changes in what and how engineering education is offered.

All teaching-focused colleagues are being co-located to a single building which is being creatively redesigned to enable the continued growth of a vibrant learning community in which students, staff and industrial colleagues can work together to provide and experience excellence in education.

Benefits of the new approach

In reconceptualising how engineering education is offered and experienced across all levels, WMG is at the forefront of a paradigm shift in which traditional models of, and approaches to engineering education in particular, and higher education in general, is changing.

WMG is quickly becoming a leading centre for creativity and individualised learning where students are seen as learning partners and care is taken to ensure that the curriculum is industrially valid, academically rigorous and of a high quality. From a university perspective, WMG is leading the way in providing evidence-based learning and teaching. Technology-enhanced learning tools and approaches are increasingly playing an important part in this and risk and creativity in learning and teaching are encouraged.

The main benefit for the students is the emergence of a more cohesive, forward-thinking, academically-grounded and an exciting future-facing curriculum, purposely designed for employability.

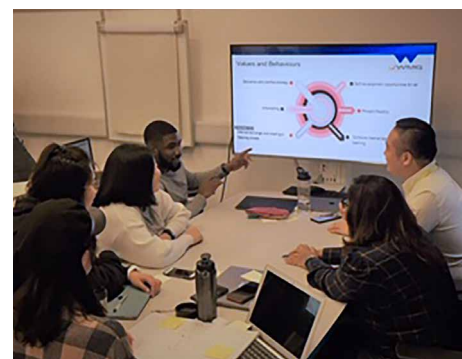
Colleagues find themselves in a fast-changing organisation whereby innovation is supported and professional development actively encouraged.

Additionally, the whole university is benefitting from a renewed enthusiasm for learning and teaching amongst colleagues within one of its largest departments.

Making the changes: learning points

Leading institutional change management is never easy, particularly in an academic setting. In reflecting on progress to date a number of points are worth sharing:

- Change in an academic setting must be grounded in evidence and unpinned by sound engineering education and management research.
- In leading strategic change it is important to gain colleagues trust. This is achieved by an approach in which the change is 'owned' at a group level, with piecemeal activities linked together to form the organisational change.
- A primary goal of the organisational change must be the creation of a forward-thinking learning community based upon an ethos of scholarship and collegiality. At WMG, the physical relocation of colleagues to a shared space helped remove physical and academic barriers to collaboration.
- Student participation is key to all change in engineering education.
- Industrial engagement should take place through a range of channels such as industrial advisory boards and smaller group discussions via engineers working in industry.
- New programmes and short courses should to be developed directly in partnership with industry and professional bodies.



Key metrics

- Female-to-make student ratio: 30%-70% for the Engineering Edge Project.

Data from the Engineering Edge Project⁴

Percentage of UK Engineering Educators' Strongly Agreeing [SA] or Agreeing [A] with a series of 'Engineering Education in the UK today' Position Statements (N = 173)

Engineering education in the uk today: position statement	% [SA/A]
No consideration is given to the time it takes to refresh learning materials annually within my workload	75
The pressures of work make giving good quality feedback difficult	73
High quality teaching is neither recognised or rewarded in my institution	66
A lack of resources at my university makes it difficult to develop assessment that fully evaluates the learning outcomes	53
There's too much attention on research over teaching in my institution	52
Teacher training at my university is not taken seriously	50
The accredited 'CPD' offered to colleagues with regards to teaching (such as the PGCHE) does not account for the distinctive issues associated with teaching in engineering	47
The learning spaces in my institution are appropriate for high quality learning	45
Too much emphasis is given on student feedback	42
Attempts to be innovative in the classroom are met with resistance from students	18

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