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The UCL Integrated Engineering Programme[1]

STEVE HAILES

LIZ JONES

MARTINA MICHELETTI

JOHN MITCHELL

ABEL NYAMAPFENE

KATE ROACH

EMANUELA TILLEY

FIONA TRUSCOTT
University College London
London, UK

ABSTRACT

In 2014, the UCL Faculty of Engineering Sciences introduced the Integrated Engineering Programme – a revision of eight existing degree programmes across a range of engineering disciplines. Centred on a thread of authentic project-based activities, the programme aimed to enhance the students' understanding of key theoretical concepts and heighten the development of key professional skills. This paper provides an outline of the rationale for the various project-based activities implemented, details their key features and described the impact these activities have had on the students' development of key skills.

Key words: Project Based Learning, Engineering Curriculum, Professional Practice

INTRODUCTION

Engineering schools have faced many calls to move their curricula away from the predominant engineering science-based model and increase the emphasis on professional skills and practice (Industry 2009, National Academy of Engineering 2004, Besterfield-Sacre et al. 2014, McMasters 2004, Rugarcia et al. 2000, Moore and Frazier 2017) with this agenda gaining traction worldwide including

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in India (Joshi and White 2020) and China (Zhuang and Xu 2018, Shaoping 2017). This has led to the foundation of new schools such as Olin College in the US and NMITE and TEDI-London in the UK, but also to significant revisions to existing curricula. To address some of these issues, the UCL Faculty of Engineering Sciences launched the Integrated Engineering Programme (IEP) across eight of its disciplines (Mitchell et al. 2019) in 2014. The Faculty covers a range of engineering disciplines including, Biochemical, Chemical, Civil, Electrical and Mechanical, as well as Computer Science and Management Science and is highly research-intensive. Typical intake is between 800 and 1000 students per year in those disciplines, with around 60% on the 4-year, integrated Master's (MEng) route and the rest undertaking a 3-year bachelor's degree with 50% of the total cohort classified as overseas. The majority of the programmes were well established and had been running in their previous form for many years.

A comparative analysis between the existing curriculum and the desired graduate attributions as described by the literature referenced above, as well as our own focus groups with alumni and employers, suggested that strong foundations in technical knowledge remained important. However, they were no longer sufficient, and that an increased emphasis was needed on 'employability skills' and non-technical knowledge. In particular, employers valued communication, project management and team working skills. Alumni were adamant that these must be integrated in curriculum and not as add-ons if they were to be successful.

The curriculum revision took a pragmatic view of existing material and looked to construct a framework whereby traditional taught elements were supported and enhanced by threads of instruction in profession skills and projects to expose students to professional practice and draw together knowledge and skills learnt in all parts of the curriculum (Graham 2018). In this paper, we describe our approach to implementing a faculty wide reform of an engineering curriculum, from both a pedagogical and a change management perspective.

PROJECT-BASED LEARNING

A range of options were considered to deliver the educational aspiration of the programme drawing on the small but growing body of literature of wide scale curriculum change worldwide. A number of notable examples where analysed including CDIO (Crawley et al. 2007), Design Based Learning (Gómez Puente, van Eijck, and Jochems 2011), the Aalborg model of PBL (Kolomos, Fink, and Krogh 2004), and various implementations in Australia (Mills and Treagust 2003, Hadgraft 1993, Godfrey and Hadgraft 2009).

The educational literature was clear that Problem-Based Learning (PBL), and its variant, Project-Based Learning (PjBL), which is commonly applied in engineering, had benefits in the development of transferable and professional skills (Shuman, Besterfield-Sacre, and McGourty 2005), although evidence for impact on technical skills was less striking and sometimes questioned, especially when measured by more traditional testing methods (Prince 2004). The history of the pedagogical premise that professional skills and practical 'know-how' are best learned by 'doing' within the context of a real-world (authentic) projects can be traced back to the work of Killpatrick and Dewey over a century ago (Heitmann 1996) and has been widely adopted, albeit often in limited forms in the engineering curriculum in the UK and worldwide (Graham and Crawley 2010).

The project-based learning activities (Bell 2010, Kolmos and de Graaff 2014, Jollands, Jolly, and Molyneaux 2012) implemented take a number of forms, but all are aligned and integrated with the taught material elements of the programme to provide a variety of opportunities for students to put their engineering skills - be they technical, professional or inter-personal - into practice in an authentic and research-led environment. Definitions of PBL and PjBL vary across the literature (Hanney and Savin-Baden 2013). One example is the framework of De Graaf and Kolmos (2003), who identified project-organised learning as a model and described three 'levels' of projects, the task project, the discipline project, and the problem project as drawn from (Kolmos 1996).

The curriculum is typified by a progression of projects, starting from 5-week *task-projects* in the very early stages of year one, which are teaching-led and highly structured. However, this very quickly moves to projects of the *discipline-project* type, more open-ended and although still scaffolded by the teacher, introducing the demand that the student groups take some ownership of the direction of the work. As students move through the first two years, they progress to *problem-projects*, highly open and requiring problem definition from the learner.

Project work has become a norm across many professional sectors including IT and engineering, yet there is still some ambiguity in received definitions in the academic literature. Hanney (2018) argues that both the fields of organisational studies and of education suffer from similar forms of sloppy thinking when it comes to defining projects as an object of study. In organisational and education literatures interpretations tend to focus on 'understanding the project as an administrative framework rather than…a practice' (Hanney 2018, p771). Worse than this, Hanney (2018) maintains that in the field of education, "It appears…that custom and practice forms the basis of a folkloric body of knowledge that attaches itself to a notion of professional authenticity for legitimisation" (Hanney 2018, p771). Such a scenario is problematic for educators whose ability to theorise projects ought, perhaps, to form the basis for any justification of project-based learning pedagogies. That said, there is a great deal of work that does show that students learn well by undertaking PjBL (Shuman, Besterfield-Sacre, and McGourty 2005).

Elsewhere we have explored the concept of authenticity and argued that engineering undergraduates do benefit from learning in contexts of projects that are authentic (Roach, Tilley and Mitchell 2018). Cognitive realism (Brown, Collins, and Duguid 1989) embodied in the combined social and technical activity of project work seemed to be enough for students to value the project for its learning potential despite the fact that the deliverables, schedules and settings were not always entirely authentic.

Since we began working with the project as a pedagogical tool we have come to conceive of it as a sociocultural practice or an activity system. The term originates from activity theory, and refers to the objectives, aims and social relations that converge in human doing, or acting (Engeström et al 1999; Hardman and Amory 2015). The central concern of the theory is to understand human activity as an object-directed, culturally formed social system which has its own structure. It is beyond the scope of our discussion to explore this theory and we use it here simply to direct focus on the project as a sociocultural system of activities that integrates interpersonal, technical, and professional aspects of engineering expertise.

The PjBL activities at UCL are designed with the aim that technical knowledge and professional skills delivered through a single culturally appropriate activity system, will reinforce learning of social, practical and professional skills and technical knowledge at the same time. Each reinforces the other because meaning is provided in both directions. This account is closely related to notions of situated cognition and situated learning (Brown, Collins, and Duguid 1989) in which context (in our terms 'the project') is understood to reinforce learning.

PJBL IN THE CURRICULUM

At UCL, the revised curriculum is centered around a project thread, but not dominated by it, with students spending roughly 20% of their time on their project work. The rest of their time is occupied by more traditional forms of instruction, which lead to (or follow from) the project work. We describe the project strand of activity as being at the heart of the student experience. Although students do experience different learning contexts, they all do projects that have a similar life cycle which are designed to draw together learning from all the elements of the curriculum, from their own discipline and cross-cutting threads such as mathematical modelling and professional skills.

The IEP comprises two broad components (Graham 2018):

1. A common curriculum structure shared by all engineering departments during years 1 and 2 of study with shared goals, format and assessment protocols across the Faculty. This common curriculum framework integrates a number of key elements:

- Challenges: two immersive five-week projects at the start of year 1 introducing students to the role and scope of engineering and setting a context for their studies;
- Scenarios: one-week intensive design project at the end of a five-week cycle to integrated critical engineering skills and knowledge developed through predominantly lecture based classes;
- Design and Professional Skills: a structured program of skills development that students can apply and build upon in their Scenarios and Challenges;

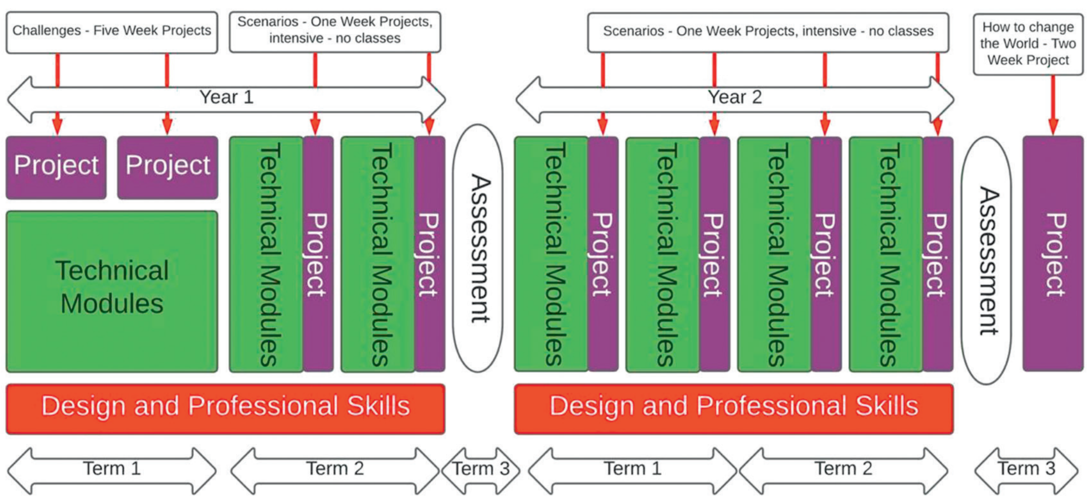

Figure 1. Structure of the IEP in the first two years of programmes.

- Minors: specialisms at the interface between engineering disciplines, such as sustainable building design, ocean engineering and regenerative medicines or out of discipline, such as languages or entrepreneurship;
- Core engineering modules: largely discipline-specific engineering subjects.

2. Multidisciplinary experiences that bring together most or all students from each year-group across UCL Engineering. These experiences are coordinated centrally by the Faculty and taught by cross-Faculty teams. They include:

- Challenge 2: the second of two five-week Challenges held during year 1, where students from across the Faculty tackle a multidisciplinary problem;
- common professional skills: a shared set of professional skills modules – around a quarter of those taught in total – that are common to all departments;
- mathematics: an applied mathematics course taught Faculty-wide by engineering faculty;
- How to Change the World (HTCTW): a two-week multidisciplinary project at the end of second year where students tackle open-ended problems within the framing of UN Sustainable Development Goals (SDGs).

The IEP focuses predominantly on the first two years of the BEng and MEng curriculum at UCL Engineering with subsequent largely determined by each department.

All students entering engineering and computer science programmes engage in two, five-week projects over the course of the first term as outlined in Figure 1 which shows the activities undertaken in these first two years. These aim to introduce students to project and teamwork skills, provide time for reflection on their practice and introduce them to the design process. The first 5-week project is discipline-based and is on a topic related to the research conducted in the student's department. Typically, students are placed in teams of 5-7 and asked to identify a problem and provide a proposed solution that addresses not only technical aspects but also financial and logistical factors. Student teams have addressed topics such as Sustainable Resources in Lagos, Pollution Control using Micro-Organisms and Earthquake Relief in Chile. The second 5-week project is interdisciplinary in nature and is taught in cohorts comprising of two or three departments. All students work on aspects of the same project. Teams of 6-11 are asked to work to a design brief to construct and demonstrate a prototype in addition to considering the influence of context on the project. Previously the central project has been the construction of a vaccine production plant with aspects such as infrastructure, control systems and vaccine production tackled by multidisciplinary teams.

Following these two foundation projects, most programmes adopt a model of four weeks of more traditional style lecture-based instruction followed by one week of intensive 'Scenarios'. This model was pioneered at UCL by Civil, Environmental and Geomatic Engineering (Bell, Galilea, and Tolouei 2010) and later implemented in Electronic and Electrical Engineering (Thomsen et al. 2010). The design-project based activities progress through years one and two, giving students the experience of different stages of design and different applications of their knowledge.

In general, scenarios are active-learning, PjBL experiences in which student teams are presented with some element of design and problem solving. In most week-long scenarios design involves detailed prototyping, specification, testing or optimisation. Many scenarios also give exposure to external partners in a range of different roles, from those who join students for a single teaching session, to those who take on a full client-type relationship with individual teams. Central to the model is the intention that the scenario is connected to the theoretical learning undertaken in the more traditional classroom setting. Predominantly it follows instruction, allowing students to apply theory and develop connections between mathematical, scientific techniques and professional skills. It provides an ideal vehicle to counter the compartmentalisation of knowledge that is witnessed in a modular structure, forcing students to draw from across the curriculum. It has also been used to good effect to introduce more highly abstract concepts prior to formal classroom instruction.

As an example, in the Department of Civil, Environmental and Geomatic Engineering each scenario is approximately 33% of a 15-credit module (with students undertaking 120 Credits per year) with students assessed directly on their outputs and indirectly through a Year 1 competency-based reflective portfolio. A key element of all scenarios is to link the professional skills curriculum embedded within the IEP framework to a technically-orientated activity. This curriculum thread introduces Year 1 students to topics such as: health and safety, ethics, leadership, teamwork, project management, contracts and communication, along with key skills in technical drawing, map production and spatial analysis in Geographic Information Systems (GIS), and computer-aided design. In Year 2 students expand their knowledge and proficiency in a similar more advanced curriculum including new topic sessions, such as those on law, commercial awareness, research skills and project risk. There is also a third parallel stream of design modules that support the development of design skills and the application of theory to enable students to develop approaches, skills and confidence to take forward into the scenarios. Therefore, as they approach each scenario, students are able to draw upon their learning from more traditional Civil Engineering modules like Structures, Fluids, Soils, Materials, Surveying and Maths, and combine it with their learning in Design, Professional Skills, Impact Assessment and their experience of the IEP Challenges.

Currently, a range of different scenario projects, including Camden Town street renewal; the sustainable design, build and operation of a new research facility; road and drainage design in rural Wales (as part of the surveying residential field course); design of a sustainable rural school in Mexico with integrated water management (managed with a partner Mexican NGO); a design for a new pedestrian and cycle bridge; and design of a new cultural heritage centre on the Godalming floodplain.

To give a sense of how a set of scenarios might fit together we take the example of the Department of Biochemical Engineering and present an overview in Table 1 showing how engineering experiences, technical knowledge and professional skills are developed in each of the scenarios. It shows how scenarios build across the two-year to encompass a broader range of skills and technical knowledge. In each scenario an industrial visit (scenarios 1 and 5), a set of laboratory experiments (scenarios 2, 4 and 6) or a computer-based activity (scenarios 3) are included to support the teaching of engineering practice. Students are initially briefed and guided through a problem, but they then independently experience decision-making, troubleshooting, judging within different contexts, designing experiments and carrying out market analyses. In all scenarios the topics are linked to one or more modules taught within the same year and students are expected to revise and apply the subject knowledge while working on their projects – highlighted as subject knowledge in the table. Whilst professional and technical skills are integrated in these projects, a variety of communication skills are tested in scenarios such as risk assessments and reflection on the team dynamics. In Year 1 the two scenarios are aimed at familiarising students with process design and flowsheets and at appreciating the scientific method via the planning and execution of research experiments. The ice cream manufacturing scenario starts with a guided visit at an artisanal ice cream factory and then students are tasked to analyse an existing company's process and re-design it based on clients' requirements. They have an opportunity to analyse historical batch data and select from an equipment catalogue while they make decisions based on mixing and heat transfer (transport processes) considerations.

In Year 2 the scenarios aim at consolidating students' knowledge of unit operations and culminate in the department's flagship activity, Pilot Plant Week, where each team is involved in a short research project, selected among different topics aligned with the department's latest research priorities.

One of the few exceptions to the one-week intensive pattern is an industry-led project run by UCL Computer Science which, due to the strong involvement of multiple industry partners who act as clients, requires that timetables are more flexible and so the project is conducted over the course of two, ten-week terms. Annually, up to 150 computer science students take on genuine projects and deliver functioning software or apps to a range of external partners, from Microsoft to the UK National Health Service, charities and local government through the Industry Exchange Network (IXN).

The IXN approaches undergraduates as 'consultants in training' who require multiple experiences of industry lead projects to learn effectively. Consequently, computer science students encounter different projects and partners or clients, from a year 1 'light-touch' industry experience to their first real client-facing task in year 2 and beyond into years 3 and 4. This provides the opportunity for students to develop the ability to manage various styles across different client sectors and projects.

The IXN projects teams of three are supported by a technical mentor from the partner organisation along with a UCL teaching assistant, both of whom meet with students weekly. Students produce and are assessed on a project portfolio, which includes the main project output as specified by the partner, along with several pieces of course-work, all of which are applied to the project environment and delivered to the partner. For example, a legal report required of year 2 students across all engineering departments is generated in the IXN from partner requirements and summarises the legal position specific to each project. Likewise, a research report, elevator pitch, longer presentation and a non-technical communications exercise are supported in workshops and translated directly into project worlds by students.

At its core the IXN has the idea of situated cognition, where learning experiences are designed around project tasks so that knowledge and experience are delivered together, creating a system in which the one reinforces the other (Brown, Collins, and Duguid 1989). Testimony to this are the useful products that have emerged from IXN such as Haskelly, the Visual Studio extension that supports teaching and learning of the programming language Haskell, and Fizzyo, the app that encourages young cystic fibrosis patients to embrace physiotherapy.

CHANGE MANAGEMENT

As might be expected in an engineering faculty, the process of curriculum development shared a remarkable degree of similarity to an engineering project. A clear brief was desirable, but as with so many engineering projects never precisely articulated at the outset due the considerable number of constraints and trade-offs involved. Within the context of the programme leadership a number of objectives where clearly identified, with the acknowledgment that in existing and traditional programmes in a research intensive university, a certain level of realism was necessary, as was observed "a balance between vision and ambition with a pragmatism about how we can make this work." (Graham 2018). This led to two important features of the model; first, a set of innovations that were disruptive enough to ensure that superficial compliance would be difficult, but at the same time providing enough space for traditional teaching methods to remain for those staff who felt unable to engage with the new pedagogies. Secondly, the model drew heavily on local precedence, which allowed staff to reflect on and experiment with the innovations being proposed. The process commonly elicited far more nuanced discussions than had previously been experienced when novel approaches had been simply presented as fait accompli. By involving staff in this way the model became the perfect foil for blocking comments, such as 'not possible' or 'wouldn't work here'.

It was also the case that a shift in culture within the university at large supported the developments. The team was fortunate to have support from all levels of senior management, not just directly but also in a much more tacit attempt at rebalancing of institutional culture in the recognition of the importance of teaching as well as research. This is probably most notably highlighted by the introduction of a new Academic Career Framework and the number of teaching focused staff appointed to support the programme. While the ultimate success of this shift should be the subject of a separate evaluation, the presence of the conversation alone offered an opportunity to engage at least some staff that had previously been reluctant. At the time of the curriculum design process, the IEP was described as a framework. This was fitting and served to ensure that the changes 'stuck' as a result of a clear structure, scaffolded with appropriate (although still not fully prescriptive) specifications. However, as the developments have become embedded, we see the emergence of an Integrated Engineering Philosophy, a set of principles that encapsulate the values of the Faculty, but that also provide space for local innovations and adaptations to occur in response to discipline specific context or practices. More importantly this philosophy is becoming a set of guiding principles for future programmes.

IMPACTS OF PJBL ON STUDENT LEARNING

As with any new program, the IEP encountered several challenges and stumbling blocks in its first year, particularly in terms of student engagement. Much of this was associated with a lack of expectation setting for incoming students, who found it hard to understand how the experience of team projects and open-ended design problems could advance their learning. In addition to this the professional skills curriculum was perceived as disconnected and irrelevant to an engineering education (Graham 2018). This was addressed by teaching teams through specific communications to set student expectations, the provision of linking materials to help students integrate their learning, and by adapting module or project curricula where necessary (Graham 2018). One of the major turning points in student engagement happened as students began applying to their first summer internships. As Graham (2018) describes, "many were surprised to find that their experiences in the *IEP Challenges* and *Scenarios* "*was all the interviewer wanted to talk to me about…he was asking about how I dealt with conflict and how I managed my time and [I found that] I had a lot to say!.*"" (Graham 2018 p11) As the first IEP undergraduates passed into senior years, they took this experience with them and communicated it to lower years.

By 2018 IEP students were embedded across all undergraduate years, and at this time a small team of UCL staff undertook short interviews with students in situ in PjBL workshops during The Challenges and years-1-2 scenario to ask them the simple question, 'what have you learnt from this experience?'. In general, technical learning was a common point of convergence for all these students. In particular, they mentioned learning practical skills such as new software programmes, programming languages, how to use equipment, how to do new calculations or how to apply some of the mathematics techniques they had already learned. All is of course self-report and was not assessed as such, yet it is an important indicator of how students conceptualise their learning.

Just as frequently students talked of group work, teamwork, and gave details about the processes that the team engaged to carry out the activity. Year 1 students, only a few weeks into their first project in The Challenges, already acknowledged the importance of the social aspects of the activity, "The main thing, I think from the start is to cooperate with different people from different backgrounds…it's quite fun to actually work with them because you get to learn new experiences…". Other more experienced teams described structured processes, deliberately conceived to make decisions and maintain social cohesion, as this year 2 biomedical engineering student explains:

> "all three of us pitched an idea to each other. We then did what's called a decision matrix where you rate each design on a number of criteria…then we gave them scores and then whichever one had the highest average score was decided."

Although students did not often refer to the abstract notions of learned communication skills, or learned teamwork skills, many did describe systems that demonstrated the impact of the PjBL experiences on learning in these areas. One year 2 Biomedical student talked of the way the team used, "different methods of keeping everyone up to date and in the loop including using Google Drive and setting an action plan for every day" and after a pause they added, "….and [we] just sort of try really hard when we get frustrated with the project and not let that become a team issue". Here processes that foster cooperation through communication, are integrated and linked to maintaining harmonious team activity.

Many year 1 students talked of a peer to peer exchange of information and knowledge that facilitated their own learning during their first term of their first year at UCL. For one student the mix of electrical and computer science students made for, "…quite a good relation" while a CS student explained, "…the biggest challenge for me was that I have absolutely no experience with electronics…so I had to really read through a lot of things and ask…[an electrical student] a lot of things, he explained a lot to me and it was so useful. So, this is on the technical side and on the team side you can rely on the other person because he knows more on the subject and you shouldn't be ashamed to ask.". Again, the activity of sharing knowledge is integrated in this student's mind with sound teamwork.

Several students described learning about unexpected hitches and, 'things that you wouldn't normally think about'. A year 2 CS student on an IXN project discovered that transferring health data from one source to another was not a straightforward business, "you might think, oh well to send a heart rate, it's just a value, whereas actually…every different hospital could do it in a different way and so building a scheme that supports…[data transfer] is…more complex than I would have imagined." Many students described navigating hold-ups and issues of this kind, which they could not have anticipated from the outset, but that required them to adapt and change their activity system to fit the context.

One of the most interesting of these areas was where students related to clients. The IXN student projects drew forth a whole range of student comments about the client relationships that show these teams learning to work with different kinds of actors within their systems and to understand their different motivations. Some described the way in which the client "has the vision", while the teaching assistant could provide the expertise on how to achieve it. Some teams spoke of trying to manage or influence client expectations, as one student put it, "…we have an experience of haggling our requirements…and the clients themselves don't know fully what we can achieve within the time frame. So, we have to…negotiate what is capable within the time frame and that is something that I guess we probably wouldn't experience if were just given some requirements…"

In describing their own lived experience of these projects, these students demonstrated their ability to integrate skills and understandings from all inputs, technical, professional, social and contextual and combine them within a single activity system in order to meet the objective of delivering assignments. All of these students articulate learning beyond technical abstractions and this appears to us to be one of the most important impacts of the core thread of PjBL in the IEP.

CONCLUSIONS

Although the majority of the revisions introduced by the IEP were based on existing practice – predominantly at UCL, but also drawing on expertise from elsewhere – the scale of the revision to a set of existing and successful programmes across an entire faculty of a research-intensive university

Table 1. Overview of scenario themes and assessment components. G: group assessment; I: Individually assessed.

	Scenario 1 – Ice Cream	Scenario 2 - Mixing	Scenario 3 – Speeding therapy supply	Scenario 4 –Biofuel production	Scenario 5 – Biofuels and Sustainability	Scenario 6 – Pilot Plant Week
Engineering experience	Unilever pilot plant visit and Q&A	Laboratory experiments (viscosity, power input, mixing time measurement)	Engineering experimentation & design; expert consultations with manufactures of therapeutics and with equipment suppliers	Laboratory experiments (kLa measurements; media preparation and bioreactor fermentation)	Brewery visit with Q&A	Short research project including laboratory experiments and/or a modelling study, each team work on a different topic
Subject knowledge	Reactor scale up/ scale-out; historical data analysis; basic unit operations; costing	Rheology, power curve, mixing time, dimensionless numbers, motor requirements, bioreactor design	Solid/liquid separations; impact of process shear stress; whole process scale down/up; process design & economic appraisal	Oxygen transfer, growth kinetics, fermentation operation and modes, yeast physiology	Energy balance and heat recovery; flowsheet construction and selection of unit operations; reaction kinetics; costing; Life Cycle Assessment	Practical experience of upstream, downstream and analytical measurements at scale
Design and Professional Practice skills	Process re-design with constraints; costing; group presentation in front of large audience	Individual unit operation design; design of experiments; technical report writing; reflection section on team dynamics	Design and execution of experimental investigations; data processing; logbook recording; consultation with experts; team presentation to peers and experts.	Using simulations to help design laboratory experiments, logbook recording, group presentation to expert panel	Balancing sustainable process design with cost targets; environmental factors important for decision making; literature review; report preparation; group poster presentation	Lab book recording, group presentation in front of large audience
Assessment	Client Mtg (G, 40%) Online quiz (I, 20%) Presentation (I, G, 40%)	Experimental design (G, 20%) Report (G, 40%) Oral session (I, 40%)	Log book (I,G, 40%) Presentation (I,G, 60%)	Panel presentation (G, 30%), Logbook (G/I, 70%)	Feedstock evaluation report (G, 40%); Poster Presentation (G, 55%); Reflective Exercise (G, 5%)	Group presentation (G), Logbook (G), Peer assessment (I)

is almost unprecedented. The central core of project activities forms a framework which, although adapted to suit differences between departments, integrates the key learning objectives of the programme. It also presents a pragmatic approach to faculty-wide curriculum development in the context of the constraints faced when revising existing programmes. Longitudinal research on the impact of the developments is ongoing, but initial findings suggest that the aim of integration of technical and professional skills is enhancing the development of key engineering competencies in this and other ways (Detmer et al. 2018, Direito et al. 2018, Nyamapfene and Lynch 2016).

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AUTHORS

Stephen Hailes is a Professor in the Department of Computer Science at University College London (UCL), UK. His research interests are in the general area of wireless and mobile systems, distributed systems and security. His current focus includes wireless sensor networks, ad hoc networks, and applications of these technologies to control of autonomous vehicles, biological and veterinary sciences. He holds a B.A. and Ph.D. degrees from the Computer Laboratory, University of Cambridge, UK.

Liz Jones is Director of Studies for the Department of Civil, Environmental and Geomatic Engineering (CEGE) and has oversight of all taught programmes at undergraduate and postgraduate level. This also includes admissions, outreach, student support, and accreditation. Liz is a Principal Teaching Fellow and is in the Geomatics Section in CEGE. She specialises in Surveying and GIS, and provides consultancy both in a technical and educational capacity. She also undertakes archaeological fieldwork, and supervises projects relating to applications of GIS to Civil Engineering, Health & Safety in Civil Engineering and the Construction sector, community engagement in Civil Engineering, and diversity and inclusivity in industry and Higher Education. Liz joined the Geomatics Section of the CEGE department in 2008 after working as a surveyor in the

3D team of Plowman Craven. She completed a BA in Egyptian Archaeology (UCL), MA in Egyptology (Liverpool) and an MSc in GIS (UCL).

Martina Micheletti is a Professor in the department of Biochemical Engineering at UCL, Departmental Tutor and Fellow of the Higher Education Academy. Her early work centred on teamworking and group assessment was awarded the Exxon Mobil Excellence in Teaching Award from the Royal Academy of Engineering. Her recent work focuses on the improvement of the student's experience via development of scenario-based learning opportunities and improvements of existing practical activities.

John E. Mitchell is Professor of Communications Systems Engineering in the UCL Department of Electronic and Electrical Engineering, Vice-Dean Education in the UCL Faculty of Engineering Sciences and Co-director of the UCL Centre for Engineering Education. Between 2012 and 2016 he was on secondment to the UCL Engineering Sciences Faculty office, where he led the introduction of the Integrated Engineering Programme. The team that led this major revision of the curriculum across the engineering faculty has recently been awarded the HEA Collaborative Award for Teaching Excellence (CATE). In 2009, he was awarded the UCL Provost's award for teaching and has published on curriculum development with engineering education. Professor Mitchell is a Chartered Engineer, Fellow of the Institution of Engineering and Technology (IET) a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE), Member of the Board of Directors of the European Society for Engineering Education and Principal Fellow of the Higher Education Academy. He is currently Editor-in-Chief of the IEEE Transactions on Education.

Abel Nyamapfene is an Associate Professor (Teaching) in the Faculty of Engineering Sciences, University College London (UCL). He is a founding member of the UCL Integrated Engineering Programme, an award-winning engineering curriculum framework which has been implemented across the faculty's undergraduate degree programmes. He is currently the academic lead for Engineering Mathematics and the Programme Director for the MSc Engineering & Education, which is a joint initiative between the Faculty of Engineering Sciences and the

Institute of Education (IOE). Prior to coming to UCL, Abel served as Director of Studies for MSc Programmes in Electrical Power Systems at the University of Bath, and prior to that, he was Assistant Director for Education (Engineering) at the University of Exeter. Abel holds a PhD in Computing from the University of Surrey, and an Ed.D. from the University of Exeter. Abel is a Senior Fellow of the Higher Education Academy (SFHEA), a member of the Institute of Electrical and Electronics Engineers (MIEEE), and a member of the Institution of Engineering and Technology (MIET).

Kate Roach is a social scientist whose overall interests focus on the intersection between human culture(s) and STEM subjects. At UCL Engineering her teaching incorporates professional skills training along with problem-based learning challenges that encourage engineering students to consider the social context for and impacts of their work. Her research interests are in engineering education, problem-based learning, employers and employability and the popular representation of engineering.

Emanuela Tilley is Professor of Engineering Education and Director of the Integrated Engineering Programme (IEP) at University College London. She is a Principal Fellow of the HEA (Advance Higher Education). Professor Tilley has established an international profile in the areas of leading curriculum development and cultural, as well as managerial, change required to support and foster innovation in engineering education within higher education. She has a strong research background and teaching practice in PBL pedagogy and assessment, including team-based learning and ipsative feedback/assessments. She leads on embedding EDI values into our undergraduate teaching through the inclusion of authentic learning and assessments throughout the IEP.

Fiona Truscott is a Lecturer (Teaching) at University College London (UCL) in the Faculty of Engineering. She is the Engineering Challenges Module Lead, runs the Integrated Engineering Programme (IEP) Summer School and is a member of the Centre for Engineering Education (CEE).