Experiences of the transition from a traditional to an integrative project-based curriculum

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Abstract

In 2012, the UCL Faculty of Engineering Sciences made a major revision of its undergraduate curricula, through the implementation of the Integrated Engineering Programme (IEP). The academic year, 2023/2024, saw the IEP celebrate 10 years of new student intake into the reformed degree programmes which aimed to enhance the skills and societal awareness of graduates through a series of project-based learning experiences, integrated with a curriculum of instruction. Over these 10 years, it has evolved - through conscious action to improve but sometimes through unintended consequences of institutional initiatives or local developments. This paper documents the reflections of two leading members of the development team and shares experiences of implementing and maintaining a major curriculum reform focused on a student-centred, active and experiential approach to learning and teaching in a large, research-intensive university. It leverages a survey of alumni to highlight achievements, challenges and perceptions of this approach as seen by both staff and students. It considers the relationship between pedagogical ideologies and the practicalities of change within existing structures and the challenges of legacy within the institution. It aims to provide insight and support to those leading and managing programme-wide curriculum change.

Keywords: Curriculum Development, Staff Experience, Project-Based Learning.

1 Introduction

Over the last decade or two, new engineering education programmes have emerged, and many traditional programmes have looked to refine and revise their offerings to meet the changing needs of graduates, industry and programme accreditation standards (Goldberg and Somerville, 2014; Habbal et al., 2024). Different models have been adopted, depending on the context of programme and whether it is a new offering or the revision of an existing programme. There are, however, key features typically shared by these models. Most acknowledge that engineers will work beyond their traditional disciplinary silos and will need to be accomplished in working in interdisciplinary teams. They also bring a focus on authentic projects from early on in their programmes and support the development of professional skills and a perspective of the engineer as a conscientious member of society who, as a designer and agent of change, will need to understand the responsibilities that they have to act ethically, sustainably and inclusively (Graham, 2018). Many examples of revisions follow established models such as CDIO (Crawley et al., 2014) which provide a framework for a curriculum that features many of these aspects.

In this paper, we offer a reflection on a major revision of existing undergraduate engineering curricula in a large, research-intensive, public university and in particular, consider what has been learned from the introduction of an integrated curriculum - one that looks to introduce the elements mentioned above, but also to ensure that they are connected and appropriately staged throughout the learning journey of the student. Although specific aspects of the change have been presented previously, (Roach et al. 2019, de Andrade et al. 2021, Hailes et al. 2021) this is the first reflective work which considers the education reform at a holistic level including feedback from graduates. We start by introducing the context of the revision and the positionality of the authors to set the background of the work. We then describe what we mean by an integrated curriculum, provide reflections drawn from the experience of the authors over the last ten years and present initial findings from an alumni survey.

1.1 Context of the change

University College London (UCL) is a large, multi-faculty and research-intensive institution comprising of 11 faculties, 76 Academic Departments, 50,000 Students and 16,000 Staff (~4500 Academic/Teaching Staff). It is currently the largest campus-based university in the UK. The UCL Faculty of Engineering Sciences is home to around 8,000 of these students and over 500 teaching staff. It has 10 departments, of which 7 offer undergraduate programmes in engineering or computer science with an intake from 2014 to 2023 of between 850 and 1050 students each year. The faculty enjoys one of the better gender balances in the sector at 37% with just over 70% of its undergraduate population being of international origin. The curriculum change process began in the 2011/12 academic session with the first cohort of students entering the revised programmes with inclusion of the IEP teaching framework in the 2014/15 session. At the time, a Royal Academy of Engineering report stressed that “change in undergraduate engineering education is urgently needed,” yet “transformation in the structure and delivery of undergraduate provision has yet to take place,” and a “pressing issue is not whether but how to change it” (Graham, 2012, p.2). The IEP and the radical revision of the existing degree programmes provides an example of the “how” for instantiating change. The IEP was enacted on existing programmes (with the exception of a new Biomedical Engineering programme) and followed existing university regulations. The roll-out started by implementing a completely new first year for all programmes in the 2014/15 session, while upper years followed the existing curriculum. The changes in the latter years then moved through the curriculum and followed the first inaugural cohort. The BEng/BSc programmes (three-year Bachelors undergraduate degree offering) saw their first graduates in 2017 while the first graduates of the MEng programmes (Integrated Masters – four-year) completed in 2018. To date approximate 8,000 students have graduated from programmes of the IEP. Further details of the IEP teaching framework can be found in Graham (2018) and Mitchell (2021). The authors are both engineering educators and educational researchers with leadership and Professorial positions in the UCL Faculty of Engineering Sciences, a research-intensive university in the UK. Mitchell is a white, western European, cisgender man with degrees in Electronic and Electrical Engineering and an MA in Teaching and Learning. Tilley is a white, first-generation Canadian cisgender female born of western European emigrated parents with undergraduate and post-graduate degrees in mechanical and civil engineering, respectively, who returned to academia after having worked for 8 years as a professional consulting engineer in the UK.

2 Implementing an integrated curriculum.

As identified above, many of the reformed programmes witnessed worldwide share the inclusion of similar themes: interdisciplinarity, active learning and/or project- or problem-based learning pedagogy, a re-centring of engineering within society, and an emphasis on skills and professional student development. However, where they significantly differ is how they bring these elements together and how they ensure connectivity between these themes. This is the basis of the art and practice of curriculum development – the process of setting out the elements of the curriculum to ensure that they interrelate, support each other, whilst most importantly, for students, allows them to recognise an appropriate progression in terms of their depth and breadth of knowledge and skills as well as individual personal and professional development. When faced with the revision of an existing programme many competing factors, such as contextual and legacy administrative, educational, financial, and cultural structures, become critically important and can place significant constraints on how much disruption of the existing curriculum is possible and therefore how much integration can realistically be achieved. In revision programmes, curriculum designers have to be pragmatic on what aspects of learning (SLO, 2009; van den Akker et al., 2003) can be changed completely, what can be refreshed or revived, what will have to be minimally adopted, and what needs to be left untouched.

The concept of an integrated curriculum is not new and further details of our argument for its introduction can be found in Mitchell and Tilley (2024). When considering the key elements of a curriculum there are many options that could be integrated. Which become the primary focus, will depend on the nature and values/mission of the institution and the express aims of the programme, aligning with what is referred to as the *intended curriculum* (Goodlad, 1979). Within the IEP, we emphasised the integration of; the disciplines by creating multiple opportunities for students to work together, the development of the individual student both personal and professional in preparation for employment and making an impact beyond graduation, and the application of theory through engineering practice and skills-based learning, via a central spine of authentic projects (Roach et al. 2018, Mitchell 2021). Other reform programmes may choose different foci. For example, integration of workplace learning (Lindsay and Morgan, 2021) where experience in the workplace is integrated with university learning rather than more common models where university learning is somewhat segregated from industry experience.

3 Reflections on Change

This section provides some key reflections from the ten years that the revised programmes have been running from two engineering educators heavily involved in the progress, as leaders (i.e. Directors) in its development and implementation as well as its delivery and evolutionary phases. Although the process of implementing change is often the focus of popular discourse, the subsequent process of embedding and maintaining the change and ensuring it 'sticks' is just as important and just as difficult. It would be easy to assume that such a curriculum development simply involved a shift to a new model that would quickly become 'business as usual' and therefore be self-sustaining. However, our experience showed that integration needs to be continuously lead, nurtured, and maintained, with new governance structures required to ensure that once the fervour of the initial change project subsides there are processes in place that ensure continued collaboration and progression towards ultimately changing the culture of education within the institution/faculty/department(s) amongst staff and students. Over the course of 10 years, we have seen many of the original staff move to new roles and be replaced and therefore the establishment of faculty level committees with departmental educational leadership engagement that ensure collective memory and responsibility for the shared elements of the programmes have been vital.

As highlighted above, any revision to existing curricula is undertaken within the context of considerable legacy. The analogy of trying to 'change a wheel while the car is still driving down the motorway' is often used. This brings a sense of pragmatism that is not always necessary in the development of new programmes (at new institutions). It requires a clear vision to change what you can, revise what you must, and learn to live with what is beyond the reach of the project. One key success of the IEP framework was that it offers this level of flexibility. It embraces a variety of teaching methods and conceptions of what engineering is to allow departments to feel ownership of the curriculum while still achieving the core goals set out for the revamped degree programmes. While having some prescribed elements (predominantly those that were shared), agreed with all departments, around them there was still significant space for departments to 'fill in the blanks' and to keep as much or as little of their existing curriculum as they needed. The newly hired central team of education-focused academic staff supported this transition, running workshops and creating cross-faculty communities of practice, to facilitate the construction of the discipline specific curriculum, which although still amounting to approximately 80% of the whole, was built around the core threads of projects, employability skills, applied mathematics and interdisciplinary minors. One key element of our learning in change management came from this process: while no change is ever wasted; small-scale change or isolated pockets of change can only go so far and may even serve to amplify the disconnect between active and passive elements of the curriculum. Our experience suggests that while change, by no means must be all-encompassing or total, it does need to be significant enough that it is felt - both by staff and students. Again, this speaks to the concepts unpinning integration and curriculum design. While it is likely (and arguably necessary), that much of the existing curriculum is reused or recycled post any revision, this must be by design. The danger of only addressing a small part of the total curriculum without any modification or reorganisation of the rest is that the result might form a bifurcated rather than an integrated offering.

The rearrangement of fundamental learning was necessary as the curricular concept implemented in many ways flipped the existing curriculum on its head in terms of its design. Typically, engineering programmes start by focusing heavily and giving all the time/space in the curriculum to teaching and assessing technical fundamentals with a high concentration of maths and science. Programme designs started at the discreet knowledge or element level, a single cog perhaps which constitutes a technical element of knowledge required for any one engineering degree like for example the topic of "thermodynamics", and then over the course of the programme developed, in stages to more complex designs - two connected cogs (i.e. thermodynamics I and thermodynamics II), and then a system of cogs (i.e. heat transfer or perhaps thermo-fluids), with more applications to actual engineering systems and their uses relevant to the discipline. The IEP reversed this. Students started with a holistic view of engineering projects – for example, they considered users in the first weeks of term and how engineering design innovations and systems might have a sustainable impact and how technology and people (and/or society) interact. Students are, of course, building technical knowledge in parallel, but this contextual shift provides a reframing of what engineering is and where its emphasis should be. Whether they work on scenarios related to biofuels, wearable technologies or the manufacturing of artisanal ice-cream and vaccines, student interviews show that working on sociotechnical projects during their degree contributed to a broader understanding of the nature of engineering practice, the potential long-term impact of engineering artefacts and their own professional identity as responsible engineers. When reorganising the curriculum, much of the skills content of latter years (originally introduced as it was necessary for accreditation), was brought earlier into the first year. This resulted in a first year with a balance between theory, skills, context, and application, all integrated and connected to provide mutual support for learning.

While interviews with first year students show an appreciation for this approach, the concept of starting with generalities and then progressively getting more discipline specific as the course progresses was not without controversy. The extant model positioning students as empty vessels, who must be filled with technical knowledge before they can engage in application was still pervasive. It is important to note that building the technical depth, rigour, and confidence within the students is still important. It is still a key KPI of most universities (including UCL) and staff, students, and employers still expect such technical depth. However, we argue, and our experience shows, that this reversal does not need to come at the expense of this depth but that by bringing authentic project opportunities and skills to the fore, students are much better placed to realise that these topics are important as they are more clearly signposted within the curriculum.

The resulting programme architecture provides a combination of foundational technical and employability skills, fundamental technical knowledge, combined with a progression of authentic projects undertaken in both interdisciplinary and disciplinary-based teams. The skills element of the IEP teaching framework was originally based on a shared curriculum, partly taught by the faculty-based central team and partly taught by departmental academic staff. This has now evolved to departments taking full ownership of this thread of learning while still based on a common syllabus. The central team now works in partnership with departments to tailor and focus this thread to their specific needs. The nature of the faculty level team is vital. Sitting outside of a disciplinary department and serving students at scale, it allowed the formulation of a team with skills highly complementary to those usually found in departments – skills in supporting the teaching of teamwork and DEI, social concepts such as critical thinking, creative thinking and decision making, ethics, sustainability, entrepreneurship, and communications etc. which are not commonly the primary focus of the academic staff selection criteria used in research-based engineering departments. The team is now viewed as a 'go to' to support engineering departments in their support of student skills development. As the programmes have evolved, and as new demands have emerged from accreditation or through the rise of AI, DEI and sustainability, we have realised that the inherent architecture of the IEP teaching framework within the undergraduate degree programmes, with threads of projects, skills, applied mathematics and interdisciplinary learning, places us in an exceptionally advantageous position for integrating new topics as they become relevant. And because of the centrality of the faculty IEP team and cross-department nature of the delivery this can be done quickly and efficiently.

While there was an emphasis on the introduction of project-based learning, interdisciplinary learning, and enhancing the delivery of skills, attention was also paid to the mathematics curriculum. Engineering mathematics underpins a considerable part of any technical curriculum in engineering, but despite that, it is often taught by mathematics departments rather than being integrated within engineering. Our aim was to produce a highly applied curriculum that placed the teaching of mathematics firmly in the context of engineering and emphasised maths as a tool for modelling and analysis of engineering problems (de Andrade et al. 2022). It is fair to say that of all the revisions, this was perhaps the most debated across the faculty. Within departments, there were communities of academics who felt ownership of the mathematics curriculum, who had the strongest voices and opinions on how mathematics should be taught within their disciplines. While many were open to change and relished the opportunity to develop a progressive maths course, the necessary process of gaining agreement across multiple departments for the curriculum (and in particular, the order of the curriculum) and mode of delivery required considerable negotiation and compromise. The resulting model comprising a large lecture-based element to student cohorts of mixed disciplines which delivered the fundamental content followed by discipline specific workshops with a mixed portfolio of assessment (coursework, exam and mini-project) represented a considerable step forward. While COVID represented a significant challenge to the project-based learning thread of the integrated teaching framework, for the IEP integrated mathematical modelling and analysis modules, it represented an opportunity to take the next step towards a truly active learning approach and flipped all the lecture content online, whilst designing in a scenario-based approach to fundamental mathematical concepts. The result is an innovative curriculum and pedagogy that is structured around a series of week-long real-world challenges which provide the context for each technical mathematic topic within the syllabi. For example, students are introduced to climate change before exploring the differential equations that can be used to model it (Graham, 2021). These 'emergency' measures provided highly successful and have been adopted and expanded to become the core of the year 1 and year 2 mathematics courses.

An alumni survey is currently underway with graduates contacted via Linkedin – at the time of writing 110 responses have been received. It looks to collect reflections from graduates on key changes as a result of the IEP on the curricula. One of the most noticeable changes is the interdisciplinary nature of the IEP, and the connections encouraged between engineering disciplines. When questioned on the interdisciplinary nature of the programme, 70% responded positively with 51% saying that it may have or did indeed influence their career decisions and 87% highlighting that they often or regularly have to work with people outside their discipline in their current roles. This seems to validate its inclusion both in terms of the benefit to students but also due to its importance to the workplace. This is significant as creating (and maintaining) connections across departments is a major change management challenge. When asked, with free-text responses, what their most memorable experience or activity with the degree programme was, 70% of those who responded identified a project-based activity. While, as expected project-based activities were seen as important to the development of employability skills, 55% of alumni respondents indicated that the IEP scenario weeks were seen as very or critically important for learning of technical knowledge while only 45% responded in the same way for lectures. This again validates our approach to creating space within the curriculum for an enhanced thread of project work.

4 Summary

Any level of curriculum reform is always a major undertaking. However, reform that crosses organisation boundaries within an institution adds additional complexity. By its very nature, an integrative programme must cross such boundaries and overcome the barriers that traditionally serve as boundary markers. We argue that while challenging, it is only with this type of integration within engineering education will we be able to create the types of graduates that are needed to meet the demands of humanity inhabiting an increasingly fragile planet in the latter half of the twenty-first century. This revision process targets both the curriculum and faculty development, as two major reviews of efforts to change engineering education (Seymour, 2001; Froyd et al., 2008) point to the importance of multifocal approaches.

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