The formation of an Engineer: A view on the engineering curriculum

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Abstract:

The development of professional engineers is a joint endeavour involving schools, colleges and universities and industry. Too often, these bodies have been siloed, influencing a single stage of linear pipeline, rather than being seen as part of a continual process that provides support to potential and professional engineers at all the different stages of their development. In redesigning our education programmes, we considered this broader view and aimed to develop programmes that connect with young people and practicing engineers outside of the traditional cohort. In this paper, we will outline the review process that took place as part of the Integrated Engineering Programme at UCL and give details of how we developed a strand of interconnected activities that forms the backbone of the curriculum across all the engineering departments at UCL.

Introduction

Engineering, as with all the creative arts, requires professionals with a range of skills, knowledge and attributes. What these might be, has been discussed at great length with a procession of reports calling for change in engineering education or levelling criticism at the current process for the development of future engineers. Examples of the well-rehearsed arguments seen include investigations of the 'pipeline' of school leavers into engineering study (Perkins 2013) and particularly the difficulties faced by under-represented groups to enter engineering (Macdonald, 2014), through to the skills developed during university level education (Engineering the Future, 2014). In addition, the Royal Academy of Engineering produced a pair of reports which looked at the process of "Educating Engineers for the 21st Century" from both the industry perspective (Spinks 2006) and the academic viewpoint (RAEng 2007), highlighting both skills shortages and skills gaps in the graduates being produced.

Similar reports and findings have occurred worldwide. In the US, for example, the National Academy of Engineering (2004) called for programmes with a "broader range of interdisciplinary knowledge", while in Australia similar calls have been made in the "Engineers for the Future" report addressing the supply and quality of Australian engineering graduates for the 21st century, published by the Australian Council of Engineering Deans in association with Engineers Australia (King 2008). In some cases, these reports have acted as a call to arms for educators (CBI 2009) whereas others have highlighted the shortage of engineers and provided a case, predominantly to government, for increased investment in the education and training of future engineers (Royal Academy of Engineering 2012, Dyson 2012).

A recurring theme is a desire for university engineering departments to produce graduates with not only the technical skills of the disciplines, but also with a wider range of transferable skills, an understanding of the societal context of Engineering and in particular an understand of how to transfer these skills into industry. In the US, a significant voice for change in engineering education has been held by Boeing (McMasters 2004). While, in the UK, the latest IET skills survey gave a stark assessment:

> "There is deeper concern than in previous years around the skills, knowledge and experience of the future workforce – postgraduates, graduates, school leavers and apprentices. One of the biggest challenges appears to be in recruiting candidates with sufficient work experience. Many employers are reporting that the content of engineering and technology degrees does not suit the needs of their organisation because the courses don't develop practical skills or practical work experience"

> IET Skill and Demand in Industry (2016)

The call for change seems clear, but what change is required? The Royal Academy of Engineering (RAEng 2007) summed the end goal up as: "University engineering courses must provide students with the range of knowledge and innovative problem-solving skills to work effectively in industry as well as motivating students to become engineers on graduation".

University's role in developing the Professional Engineer

It is generally accepted that university programmes do a pretty good job at imparting knowledge. Skills can be a bit more tricky, while the develop of the attitudes and attributes that industry say they require are the most difficult of all. However, we must also remember that it is not solely the responsibility of higher education institutions to form professional engineers but a joint responsibility of both academia and industry, and a process that should, ideally, be tackled collaboratively. We suggest that fostering this collaboration is an important conversation, one that has not been fully engaged in thus far, but one that bodies such as the Institute of Engineering and Technology (IET) are exceptionally well placed to facilitate.

We should remember that graduating with an engineering degree is much like passing your driving test. It is not a recognition that you are an expert driver but merely that you have reached a sufficient competence that the next stage of your development and practice can be undertaken without strict supervision. Mirroring this, it is vital that we move away from demands for 'oven-ready' graduates and the provision of narrowly focused degree courses, and uphold education as mind-expansion, not training. Together, universities and employers need to embark in a constructive dialog as to what the shared roles and responsibilities are in the formation of professional engineers. Such a collaborative approach is required if we are to attract and keep talented young-people from the broadest range of backgrounds and gender in the profession.

As part of this development, it is the responsibility of the engineering academy and engineering educators to review and analyse the requirements of becoming a professional engineer and adapt their curriculum accordingly. We argue that this is not something that can be done piecemeal, or by one off, separate or extra-curricula activities, but something that must be explicitly embedded into the core curriculum. This does not mean that complete revision is required. It does, however, mean that the whole curriculum must be considered as part of a fundamental review of how each element contributes to the formation of a professional engineer. It should also be the case that we are willing to identify elements that are not best delivered as part of a university programme and that would be better learnt 'on

the job', within an apprenticeship, as part of an internship or placement, or after graduation as part of a graduate training scheme.

Need for collaboration

Recently at a roundtable event hosted by the IET, leaders amongst the engineering schools across the UK and senior staff of Industrial partners, both corporate and enterprise, came together to discuss if the current offering of engineering degree programmes was properly servicing the industry's needs. The main topic of discussion tiptoed around whether or not a wholly interdisciplinary degree that breaks down boundaries between specialist departments and employs the very latest methods in achieving stretching educational outcomes was desirable. However, the conversation tended to lean towards addressing the roles both the HE institutions and industry employers play in contributing to and supporting a graduate's transition between academic study and industry practice. What wasn't discussed but perhaps should be the hot topic of discussion between academia and industry, is the question we pose here "how can the two contribute to and support graduate engineer's life-long learning?".

The MEng or integrated master of engineering science programme, currently offered and accredited across the UK, is recognised as being the basic training required by the Engineering Chartership application process. Following from that, Chartership is only possible once substantial experience is gained and competence is demonstrated. After a student graduates from such a programme, there cannot be the expectation of a fully formed engineer. The only expectation should be that the students have the capacity to further develop in their own professional skills and their understanding of the world of practice, in addition to the areas of engineering thinking, design, analysis and implementation. Education prepares pupils for a life-long career in learning, not just graduation. A formal and continuous University-Industry partnership aimed at fostering the future development of graduates as life-long learners and driven to create relevant and beneficial interactions for all involved.

Currently, much of the emphasis placed by employers during graduate recruitment and graduate training schemes is getting new recruits ready to be integrated into the company, the industry sector and their new working teams. In turn this puts pressure on academic institutions to assist in this endeavor with the aim of improving graduate outcomes and employment statistics. These efforts are often focused on getting the most out of the graduate's first year or two at a company which, as evidenced by the IET report (2016), is for many, their first industry work experience. Admittedly, the years spend after graduation are formative. Arguably, it is the years after which will have them making contributions to society and creating the most impact. This shouldn't be left up to the industry sector alone. A working partnership between Universities and Industry partners both established and emerging, could support the formation of a life journey throughout a practicing engineer's working career.

Some obvious ways in which this could take form are via alumini / mentoring programmes, CPD opportunities and internships and/or hiring programmes. Beyond those, there could be ways to put into practice a 'pay-it forward' initiative, aimed at informing future cohorts within a range of levels, of the changes in the workplace and industry practices as well as continuous learning opportunities. This could help break

down the barriers between the two bodies which are currently focused on the hand-off which occurs after graduation.

Progress so far: The Integrated Engineering Programme

The Integrated Engineering Programme at UCL, better known as the IEP, is not a distinct programme so much as it is a teaching philosophy. Its key aim, is to give students across the faculty, regardless within which discipline they've been inducted, an abundance of opportunities to put into practice their core technical knowledge and develop their own 'transferable' skill sets. Authentic and research-based learning practices have been embedded in each of the departmental BEng and MEng degree offering. It makes use of active learning techniques, such as problem-based learning, which is rich in real-world context and complexity, to consider such things as stakeholder needs, design, ethics, risk, environment, costs, timelines, estimation and decision making. Those dedicated to IEP teaching, make considerable effort to create authentic assessments which reflect work commonly expected of graduate employees and/or are set out and assessed by Industry partners. Additional elements of the IEP including: an applied teaching and learning approach of fundamental mathematics for engineers; curriculum dedicated to skills-based teaching and learning; and an effort to support the student's own self-awareness of personal strengths, weaknesses, values, own working and leadership styles etc., all have aims to facilitate each student in their individual learning journey towards graduation and beyond.

The IEP created time and space in the curriculum for students from all departments within the Faculty to participate in nine distinct, diverse and technically challenging projects before the third year of their chosen programme. Whether classified as a Challenge or a Scenario (see Bains et al 2015), each project provides students with an opportunity to consider a new set of stakeholders whilst working: with a new academic lead and often industrial client(s)/advisor(s), amongst a new student team, towards a new timeline with new deadlines, within new learning environments and to submit or present new project deliverables. Evaluations reports from the ninth and final two-week intensive, inter-disciplinary project called How to Change the World, which has student teams tackle socially driven 'wicked' problems (https://www.ucl.ac.uk/steapp/how-to-change-the-world), have highlighted the ability of students on the IEP to pull their team together and start projects off proficiently and resourcefully. This, partnered with new remarks by academic leads and external third party partners, that student solutions provided at the end of the two weeks have also been improving in terms of technical feasibility, social desirability and costing considerations, are just a few observations which suggest that elements of the IEP can help students translate their engineering education into the day-to-day work of engineering.

Another distinction of the IEP is the embedding of a 'Minor' within the departmental BEng/MEng degree programmes. Much like a pedagogic framework often associated with North American undergraduate degree programmes, the IEP Minor comprises one-eighth of the second year and one-quarter of the year three studies for all students within the IEP. The aim of the IEP Minor is to offer the students an opportunity to dedicate their elective/optional modules and enable in-depth of study

in an associate area which is either linked to industry sectors (i.e. nanotechnology, sustainable building design or crime & security engineering etc.) or is skills based (i.e. programming, management or foreign languages etc.). An additional founding principle of the IEP Minor is that it must be offered to students from more than one discipline, thus making it interdisciplinary in nature. Recently an event was held to bring together industrial partners and graduate employers with IEP students to discuss the career pathways aligned with their chosen IEP Minors. A comment after the event from one of the industrial partners present reflected an intention set out by the IEP, which was to align curriculum with industry sectors both traditional and non-tradition to the disciplines offered at UCL.

> "You may find that the majority of your students will find future employment aligned with their 'minor' rather than their chosen field of engineering"
>
> Sinisa Stankovic, Rapiere Software Ltd. (2017)

It is recognised, by all associated with the IEP, that authentic learning (including PBL), enquiry-based learning and skills-based learning are all suitable and often successful ways of providing students opportunities within the curriculum to develop practical skills. Equally, however, it is acknowledged by many that these can only go so far. Direct industry engagement and work experience is arguably the best approach and the IEP is actively aiming to further advance our curriculum and industry based services to bring opportunities for interaction to the fore. Investigation into how best to position work-placements so that all IEP students graduate with work experience are ongoing. We are also exploring how we can work with our graduate employers to improve their graduate training programmes to align with skills-based pedagogies and developmental activities of the IEP. At UCL Engineering, a team of staff designated to student careers and employability currently sit at faculty level with academic staff appointed within department to leading efforts in career guidance, internships and student recruitment. These are often the people who do the most to bring industry onto the campus and supporting the students within the curriculum. There is a common strategy amongst all to increase the amount of interaction and influence on the students while they are visiting. This often takes to the form of paired engagement activities like talks on CV writing, assessment centre support or work-place culture with assessment of project work or presentations. A concerted effort towards the development of key relationships with new alumni is also a new strategy for the IEP which is hoped to help pay-it-forward and inform students throughout the IEP of employer expectations of graduate employees, but also provide information on the level of support available to develop individual capacity for becoming a professional engineer.

Summary

In this paper, we have outlined our vision for a new model of engineering education that balances the traditional demands for a broad, discipline-based education with the integration of professional engineering skills. We argue that the formation of a professional engineer is a joint endeavour between academia and industry which requires continued collaboration and cooperation, throughout the degree programme

and through into the work-place. To effectively do this, the degree level curriculum of engineering programmes needs to be overhauled, so that room is made for authentic learning experiences that allow students to integrate their academic learning with relevant practice in collaboration with industry.

As an example of how this might be done, we share our experience of developing the Integration Engineering Programme (IEP), a framework that is shared across all engineering programmes at UCL which aims to integrate theory and practice lead activities with research-based and industry-led opportunities. Although, with regards to industry interaction, this programme is still a work in progress, we believe that the framework provides a range of opportunities for direct industry interaction which can be exploited in the coming years to provide a fundamental shift in the experience received by our graduates.

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