Trends and issues for engineering education in the UK

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Introduction

The chronic shortage of skilled engineers is one of the main and persistent problems for UK engineering industries. According to the most recent UKCES report (UKCES, 2014), the engineering workforce will continue to have a strong long-term influence on the UK economy. They predict the continuing transformation of the traditional manufacturing sector to a highly sophisticated and innovative industrial sector (Dickens et al., 2013). This new industrial sector with a high level of technology integration will lead to the emergence of new multi-disciplinary technical qualifications. Engineering skills will have a greater importance within the industrial sector generally. Consequently, there will be a strong demand for engineers with a recognised level of qualification over the next decades (Wilson and Hogarth, 2013).

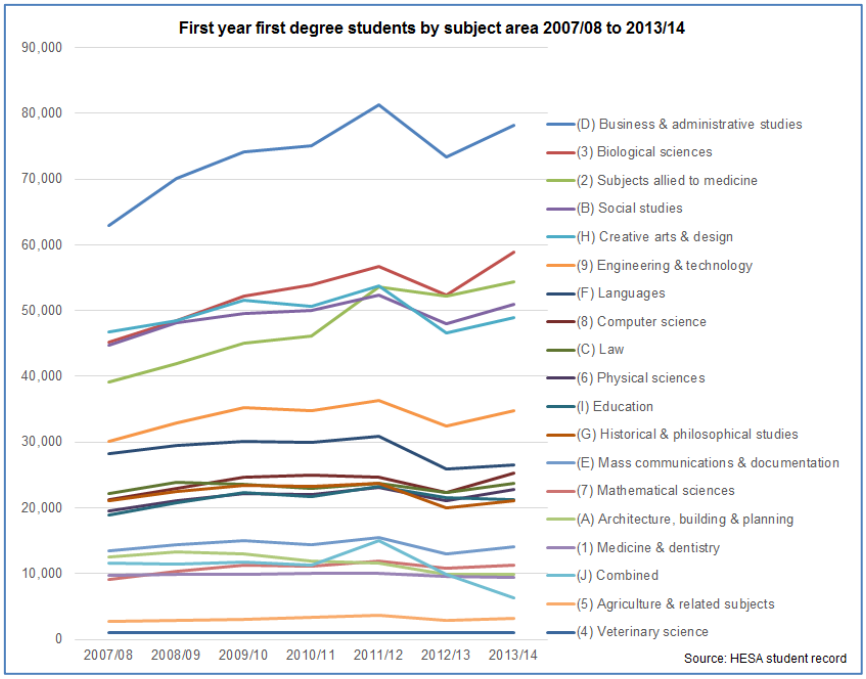

Figure 1: The evolution of student number by field of study (Source: https://www.hesa.ac.uk/pr211)

To fill the gap between needs and availability, further and higher education needs to increase the number of STEM students and adopt a learning and teaching practice that focuses on the development of new skills. Overall, the number of higher education students in UK universities has increased by one third in the last decades (HESA, 2014). This increase is more significant for the number of postgraduate qualifications (44%) and postgraduate

research qualifications (41%). With this growth trend, the global UK workforce is becoming more highly qualified. Despite this increase in student numbers, there is only a moderate growth in engineering degrees (15% in the last seven years) compared to the other study fields as evidenced in the data of Figure 1.

However, there is a constant need for degreed engineers in industry and the demand exceeds supply in the labor market. To satisfy the industry demand, it is suggested that universities double the number of engineering graduates they produce. This shortage of skilled engineers may be a critical issue for innovation development in the UK in the coming years.

The UK Context

The modern professional engineering identity emerged from the beginning of the nineteenth century, with the foundation of professional engineering societies based on the industry they served. From this time, engineering became a distinct profession and science (Tryggvason and Apelian, 2011). The UK has a rich industrial heritage based on the creativity, knowledge and skills of its population. Pride in this heritage manifests itself when surveys are conducted to identify 'Great Britons'. One of the most commonly identified figures is Isambard Kingdom Brunel the great Victorian engineer and the person responsible for many innovations in transport, buildings and public utilities (Brunel, 2011).

Despite this pride, young people in the UK do not appear to value the pursuit of an engineering career. The numbers of young people enrolling on engineering courses at college and university level remains a cause for concern. A major reason for this is the perceived difficulty and unattractiveness of the courses that manifests itself in the teenage years as students turn away from the study of STEM subjects in general (Clark and Andrews, 2010). The recent A-level results in the UK showed another yearly drop in the number of students taking physics and technology courses, although mathematics does appear to be on the increase.

To resolve this problem, the UK government has introduced several actions to enhance the number of first degree engineering students. For example, the 'Tomorrow engineers' programme that aims to encourage young students (from the age of 11 years) to become engineers.

Engineering Higher Education in the UK

The engineering higher education system in the UK has two key drivers: 'Engineering benchmark statements' for individual subjects and 'UK Engineering Council Framework' (UK SPEC). Universities and Colleges are expected to adhere to the principles of each of these and incorporate the content (where specified) into their curricula. The recently revised Engineering benchmark statements (QAA, 2010) define the academic standards expected of graduates with an engineering degree at the honours level and at the integrated master's level. This revision has brought them a lot closer to the Engineering Council Framework, so now there is greater coherency between the two.

On a more discipline focused level, there are a range of Professional Bodies representing each different engineering discipline (e.g. mechanical, electrical, materials, chemical etc). Each Professional Body has created its own accreditation system, so programmes are

accredited based on the discipline system. There is though, an overarching body, the Engineering Council, whose framework guides the individual Professional Body systems. This framework is designed to guide a person towards becoming a professional engineer. Each Professional Body has the freedom to interpret the framework how they wish and thus develop an accreditation system that suits their requirements.

Universities also have the autonomy to develop their curricula in the way they wish, but there are some common trends that should be noted. Sustainability is an area of increasing interest, as are those relating to innovation and entrepreneurship. The inclusion of management and transferable skills is an ongoing debate as the concern is always around the reduction of technical content as a way to make way for these areas in the curriculum. Universities stay aware of reports such as recently produced by Sir John Perkins (Perkins, 2013) and respond as they see fit.

Until September 2015, universities were only allowed to enroll an allocated number of students for each discipline area. This number was negotiated to some extent within the institution, but would then be approved by central government. The number has had a tendency to grow year on year in recent years as the government policy has been to expand higher education and make it available to more people. Now, entry to an Engineering Degree programme in the UK is determined by each institution separately.

These elements of institutional and academic freedom promote a regular reflection and refreshing of the engineering training in the UK, in what is a very dynamic environment. This strengthened autonomy is a new opportunity for engineering higher education institutions to reshape their academic identity by breaking down of boundaries between the academy and society (Henkel, 2007)[1].

2015 has seen a new issue manifest itself in terms of consumer protection law. The result of this step is that degree programmes in all disciplines are now subject to the same consumer laws as any other purchase a person may make (UK Government, 2015a). The fear is that this step will stifle innovation and make universities increasingly risk averse when it comes to developing their programme portfolio. Along with this development, the UK Government will publish a Green Paper in Autumn 2015 that will explore a revised quality assurance approach linked to a National Teaching Evaluation Exercise (UK Government, 2015b). This new development is on the one hand viewed as ‘even more measurement’ whilst on the other it has the potential to raise the profile and status of learning and teaching in higher education.

Challenges and Opportunities

Having a strong engineering sector is vital to maintain the global competitiveness and national development of the UK. Taking a long term view, improving the availability of degreed and highly skilled engineers is a critical issue for economic growth and sustainability. For this reason, encouraging more and more young students to pursue STEM career is necessary to meet the demand requirement. Actually, it remains difficult to recruit graduate engineers in the industrial sector because of the high demand for them on the

[1] As an example, the introduction of new practices like work-based learning, higher apprentices, knowledge transfer or technical consultancy in a knowledge based society gives a good opportunity to link together several organizations and generate innovation.

labour market (Engineering UK, 2015). However, despite this high demand for graduate engineers, engineering companies will not recruit if they feel the candidates are insufficiently qualified or matched to their organisation. Consequently, the engineering higher education system needs to put more emphasis on preparing students for their future professional practice by giving them an updated set of skills (Kalman, 2014). Therefore, not only the quantity of the graduate engineers but their quality is equally important in the transformation process of engineering higher education (Tryggvason and Apelian, 2011).

We identified five major issues having a significant impact on the evolution of UK engineering higher education. Two of them are internal influences: the progress of national engineering higher education policies and the international mobility. Three are external influences: the growing global competition in the international engineering student market, the modification of the socio-economic environment and the industry development in the UK.

Progress with national engineering education policies

The approach to engineering higher education is very much driven by the standards identified earlier. Having said that, the pedagogical approaches now being used have been informed by work such as that from the Royal Academy of Engineering (RAE, 2007). The promotion of active learning approaches and the increased consideration of the CDIO (Conceive Design Implement Operate) framework are all advances that have helped to develop more industry ready graduates (RAE, 2010). The thriving Engineering Education Research (EER) community is a testament to the developments being considered and implemented. The culture is now much more one about understanding before implementation, something that was captured in the outputs from the National HE STEM Programme that concluded in 2012 (RAE, 2012).

Policy is generally developed through a consultative process that brings together government and their representatives with professional / industry / education bodies and individuals. This process is robust in that it captures a range of different viewpoints that are then developed by parliamentary committees and subsequently the government of the day to form policies that are then taken forward for implementation. National strategies and the development of engineering talent is best captured at present by the UK Government Policy Paper titled ‘Our plan for growth: science and innovation’ (DBIS, 2014) published in December 2014. Combined with the Perkins Report (Perkins, 2013), these represent the latest thinking concerning the development of a skilled engineering workforce in the UK. A broader statement on UK Government policy for the industrial sector which clearly embraces engineering is presented in the April 2014 ‘Industrial Strategy Progress Report’ (HMG, 2014). Looking forward, the Royal Academy of Engineering Call to Action from autumn 2014 emphasises the need to keep the discussion around engineering graduate numbers and how the graduates are educated live as more changes are needed.

Degrees from different institutions are viewed in a range of ways by employers. The rationale behind this is often unclear, but accredited degrees are the most valued. The hierarchy is based purely on experience and perception and is not a written down statement relating institutions to each other. Different newspapers and organisations in the UK take data relating to what universities do and create league tables of universities ranking them against each other (Examples are The Guardian, The Complete University Guide etc).

In considering the suitability of engineering graduates for the marketplace, the main driver is the accreditation framework. The Engineering Council (EC) framework is developed with industry and academic input and is designed to capture the skills, knowledge and understanding required by the engineering industry. Accredited courses are therefore viewed as the most appropriate for the development of industry ready graduates. Having said this, the EC framework operates at a relatively high level and does not always capture the detail of the requirements. Reports such as those produced by the Royal Academy of Engineering (RAE, 2007) add some detail and influence the design of university degree programmes. The skills, knowledge and understanding requirements are a dynamic feature of the industry, changing and developing as new industry and government reports are issued. An example is given below.

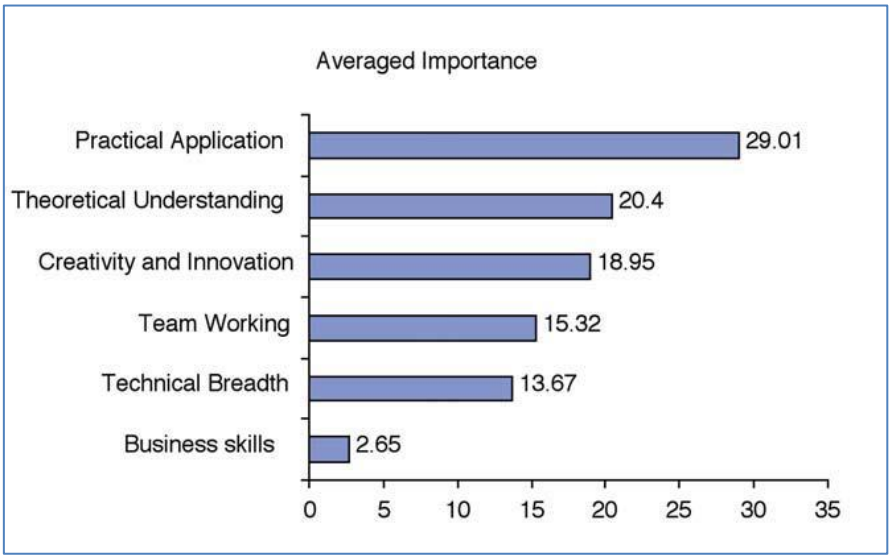

Figure 2: The average importance of skills for engineering students (Source: RAE, 2007, pp. 9)

The accreditation bodies differ in their requirements and also the university interpretation of the accreditation requirements may be different. This means that accredited programmes in the same discipline may take a different form in different institutions, although there is likely to be a core that is quite similar in each case. The requirements for what constitutes a degree at a particular level in higher education are clearly defined by the Quality Assurance Agency (QAA) and are common across all of higher education.

In the UK, the aim of engineering degree programmes is to produce graduates that are ready for industry. To achieve this, the focus is very much on the development of employability skills. In particular this covers the ability to work as part of a team (often involving cross-cultural considerations), the ability to solve problems and finally the development of creativity and innovation skills that will encourage a more entrepreneurial approach to work after university.

People with no formal educational background that have developed as a result of an extensive employment history are eligible, if desired, to apply for recognition through the EC framework. The professional body process for enabling this development and recognition of individuals is well defined, although each individual will be considered based on their own individual experience. To achieve the highest level of recognition, further training / education

may be required. Engaging with this process is completely self-driven, although individual companies may encourage and support employees to pursue this goal.

On the whole, there is a perceptive transformation of engineering higher education policies to bring education and professionals closer together. With a growing academic autonomy, engineering higher education institutions can implement new active learning approaches for the development of the new skills needed by industries.

International mobility

Student and staff mobility in the UK is not good when considering going outside of the UK. Graduate mobility is better as graduates are often willing to go where the work takes them. The most popular destinations for UK students are three English speaking countries: the United States, New Zealand and Ireland, whereas EU countries have a lower popularity (Cf.: Figure 3). Incompatibility between study programmes, term times, language skills and a general lack of desire to travel are the main barriers to student mobility. In terms of language skills, although teaching may be in English and students overseas may be competent in their command of the English language, UK student concerns that they may struggle to make themselves understood outside the teaching environment for an extended period are often very real.

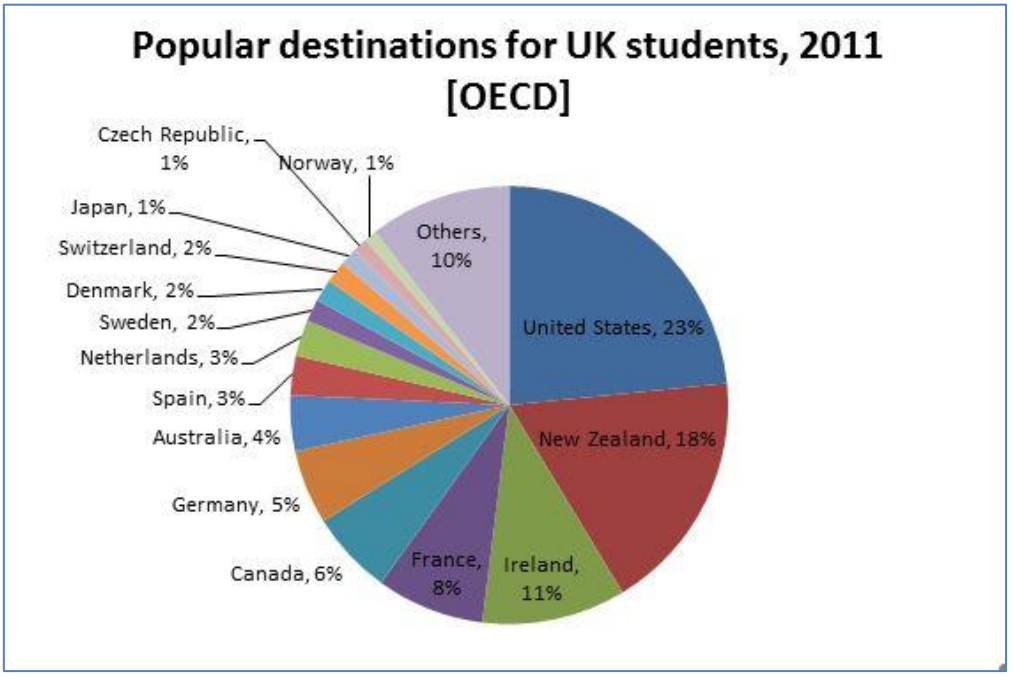

Figure 3: Popular destinations for UK students (Source: http://www.go.international.ac.uk/content/where-do-students-go)

The most recent and very thorough report to explore this subject suggests that only around 6% of UK students have some form of international experience during their degree programme (Carbonell, 2014). Numbers are rising, promoted by the ERASMUS programme primarily, but they still remain very low. There is some breakdown by discipline, but the focus of the report is very much on the numbers going to specific countries.

Considering the mobility of foreign students coming to the UK, the numbers are greater[2]. Due to fairly strict visa requirements, students from outside Europe have to return home. EU students typically do the same, although the same restrictions do not apply. Part of the reason for this is that most mobility occurs part way through degree programmes, so students must return to their home institution in order to complete their course of study.

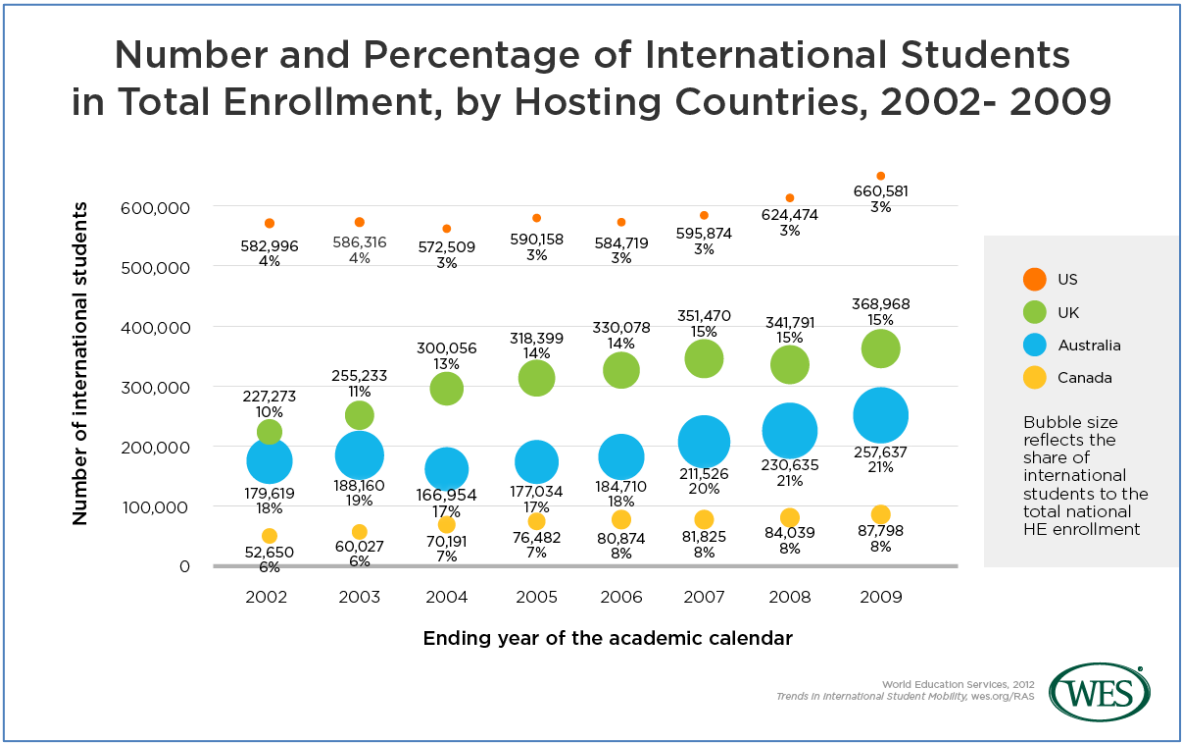

Figure 3: Popular destinations for UK students (Source: http://wenr.wes.org/2012/02/wenr-february-2012-trends-in-international-student-mobility/)

Concerning outward mobility, that mobility correlates with the number of enrolled students in the institution: a higher number of registered students tends to lead to higher mobility (Carbonell, 2014). A particular point to consider is the difference in mobility recorded by the different university types (Russell Group, pre-92, post-92). This may be down to individual university strategies and resource availability to enable mobility as much as anything.

Staff mobility is often restricted due to the demands placed on staff at their institutions. As workforce efficiency becomes more important as a consequence of the funding regime for higher education, the opportunity for staff to take extended periods of time to 'be mobile' outside of conference attendance and project participation, becomes increasingly difficult. Visiting positions are often seen as an interim possibility. Inward mobility is generally more possible. UK academics are willing to welcome colleagues from outside the country, but their own mobility is often difficult.

The need for mobility is becoming increasingly apparent to UK universities and it is likely that in the coming years a more positive approach will be taken with the necessary support

[2] A visualisation of inward mobility is given on the British Council website (http://www.britishcouncil.org/education/ihe/knowledge-centre/student-mobility/uk-student-mobility-interactive).

infrastructure being provided to support the different types of mobility. UK universities and UK industry aspire to be world-leading; consequently the awareness of global issues and gaining global experiences will be essential for both groups to realise these goals.

Global competition in the international engineering student market

There is an increasing global competition between higher education institutions for home and international students. In this global competition context, institutions have to market themselves on the national and international level (Hemsley-Brown and Oplatka, 2006): establish their market position and create their institutional image in the market. According to the empirical study of Ivy (2001), old and new UK universities apply different marketing strategies for constructing their institutional image. On the one hand, old UK universities focus on their product and heritage as a central element of their strategy (e.g. staff reputation, research results, high quality of teaching, large variety of courses…). On the other hand, new UK universities do not focus solely on product but communicate through a wide range of promotional marketing activities (e.g. open days on campus, direct mailing, promotional activity in secondary schools…). In their communication, they often put an emphasis on the facilities offered (e.g. sport facilities, convenient student accommodation, student union…) to their students.

In the international student market, not only the institutional image but the institutional reputation highly influences students' decisions (Nguyen and Le Blanc, 2001). The facilities offered for students have a positive influence on students' perception of the institutional image and reputation. Thereby, the institutional image of a higher education institution is strongly linked with the perceived value and quality of the institution and with the satisfaction of the student (Brown and Mazzarol, 2009). For this reason, marketing activities became a necessity for survival in an increasingly competitive and commercial environment.

The differentiation of the higher education institutions gives them competitive advantages on the international student market (Douglass, 2004). Undoubtedly, there is a growing tendency of specialisation in the international engineering student market. The new generations of students have more and more diversified career plans often with interdisciplinary degrees. As a result, they have greater expectations and demands for a higher level of education service customisation (Tryggvason and Apelian, 2011).

Traditionally, UK engineering education benefits from a good international reputation and recruitment both domestically and internationally has not been a problem. The £9,000 fees regime for Home and EU students does not at this point seem to have had an effect, although things may change in the future. There is and will continue to be concern that the high fee amount and the potential for large student debt will deter some students from going to university.

Engineering higher education institutions are essentially state funded. They receive their funding directly from government on the basis of their performance according to the quantity and quality of their teaching business (teaching allocation) and research activity (research allocation). There is a considerable difference in the amount of funding that the different universities receive from student fees and from the Higher Education Funding Council for England (HEFCE). Essentially they are financially dependent on the government, although they have a very large decisional and functional autonomy. Since the reforms of 2011, UK universities have to finance their teaching costs from student's fees rather than state funds

directly. Consequently, institutions are no longer viewed as public service institutions but more like part of the private sector serving their student customers (Brown and Carasso, 2013). Therefore, the development of relationship marketing is a new trend to ensure the presence of a student customer friendly environment.

Modification of the socio-economic environment

In the UK, being an engineer is not viewed as positively as in many other parts of the world (e.g.: Australia, USA, France, Germany etc). The professional image of the engineer suffers from the lack of social understanding and has a negative effect on student recruitment and retention (Yurtseven, 2002). The word engineer has become somewhat corrupted in its use. For instance a car mechanic is considered by many as a typical example of an engineer. There is an ongoing debate about whether or not the profession and word engineer should be protected in law. A change in public perception will likely help the profession appear more attractive, but unfortunately progress is slow. Organisations like the Institution of Civil Engineers (ICE) have realised this problem and work on the issues to identify ways to promote the profession in a positive and accessible way.

To facilitate professional recruitment, increasingly universities are offering Foundation programmes in an attempt to bring more people into the profession. These are people who are not ready to go straight into a Bachelor's degree but need some additional education ahead of that. Sometimes these degree programmes can be industry specific with a strong industry steer on the content and focus. Another manifestation is the Engineering Council and Professional Body push to register more Engineering Technicians and Incorporated Engineers.

According to the European Labor Force Survey (2007), the UK has the lowest proportion (9%) of female engineering professionals in Europe. It is evident that young female students need to be encouraged to consider a STEM career. However, they are traditionally not attracted because of a deep-rooted stereotypical perception of engineering as a profession that is more suitable for men. To change this perception there is a need to raise young people's awareness about the modern engineering profession (Andrews and Clark, 2012). For the economic development of the UK a higher participation of female professionals is necessary to reinforce the engineering workforce on the national labour market (Engineering UK, 2015).

For engineering employment there is an important difference between the industry sectors in terms of starting salary for graduates (Cf. Figure 4). These values compare well against the mean graduate starting salary of £21,000 in all sectors (data from 2012/13). Males generally earn 12.5% more than females. In 2012/13, the UK produced 15,620 engineering graduates (13,260 male, 2,355 female), of which 8.7% were unemployed after 1 year from graduation. The average starting salary for a graduate engineer is between £20,000 and £25,000, but this will depend on the graduates qualifications and experience and the industry sector in which the job is located.

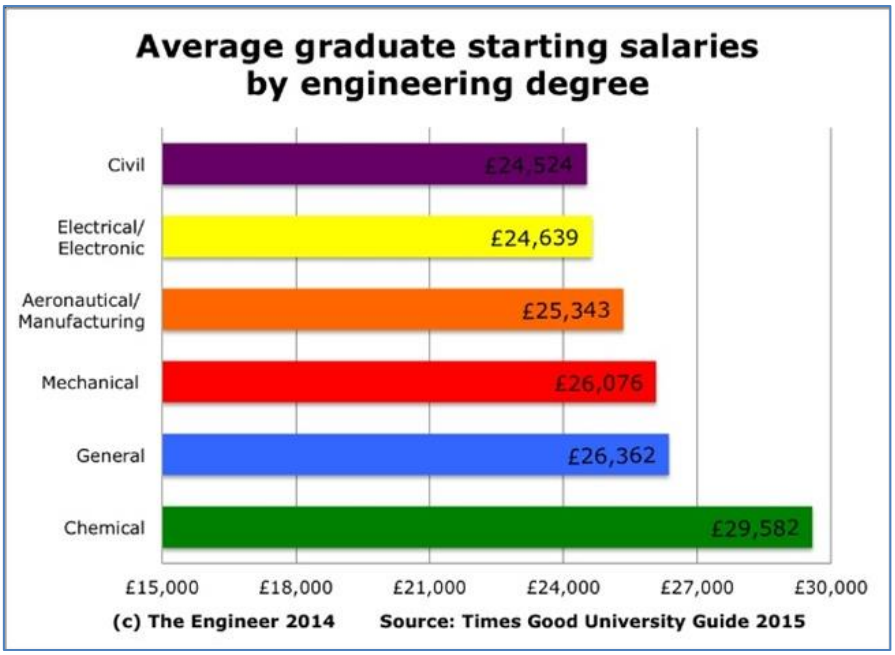

Figure 4: The average graduate starting salaries by engineering degree (Source: http://www.theengineer.co.uk)

As evidenced by the data, the UK has a high demand for engineering talent, but graduating less than 20,000 engineers a year and not seeing an increased interest in engineering in the school sector, those people that choose engineering and go on to complete their degrees successfully and to a high standard are much sought after. Despite the high demand for graduate engineers, engineering companies will not recruit if they feel the candidates are insufficiently qualified or lack the skills they are looking for. In other words companies won't recruit just because they need engineers.

Industry development in the UK

UK industry has had an important structural change over the last decades. The size of the manufacturing and agricultural sectors has significantly reduced whereas there has been a constant growth in the service sector. At the same time, the nature of the work and the workforce in each industrial sector has been transformed with new requirements by industry for graduate engineer's skills. Therefore, industries and universities need to develop closer collaborations not only for research activities (D'Este and Patel, 2007) but for teaching activities as well to develop a work related learning practice for a better matching of engineering skills to the real requirements of industry. In this way, universities have to enable their engineering students to gain practical experience of industry as a part of their engineering training.

At this time, placements of engineering students are not compulsory as in several countries in Europe (e.g.: Germany, France, etc.). However, universities are encouraged to do it hence most them try to offer opportunities to their students. Surprisingly, student understanding of the value of placements is mixed. Some see the value of industry engagement; others do not in accordance with their different personal motivations (Balta and al., 2012). It has been proven by the empirical research conducted in the UK by Mendez and Rona (2010) that there is a positive effect of industrial placements on obtaining a higher result in the final year of engineering degree. Within universities, careers and placements teams introduce the idea

and then support students as they explore what is possible. Students can visit the Careers and Placements office if they have questions or need additional guidance.

In some areas (geographical and industry) industry engagement can be problematic. The lack of industry placement opportunities precludes having 100% coverage. To alleviate this, some universities are also offering study placements (home or abroad) or mixed study / industry placement opportunities as they strive to achieve the 100% target. The 100% target is in many universities aspirational, but through a process of raising student awareness and developing industry contacts, universities are working to get as close to 100% as is practically possible. The reluctance of industry to provide placements is not well understood but is believed to be a mixture of business considerations (taking a placement student not being seen as of value) and a lack of knowledge about what placements are. There are no incentives for companies to take placement students nor is there any legislation requiring companies to take placement students.

Traditionally, UK engineering had a pragmatic approach to engineering education where work related learning was considered as the best practice to train engineers. In the course of time, due to the extension of technological complexities, this practice shifted to a scientific approach (Tryggvason and Apelian, 2011). Recently, the Government has prompted a stronger push to develop apprenticeship opportunities and higher apprenticeships (with university collaboration) to ensure a more appropriately skilled engineering workforce at the Technician and Incorporated levels. Higher apprenticeships are a new feature of UK Higher Education from 2015.

In an increasingly competitive international environment, innovation became a necessary condition for the profitable success of UK industry. Established in their empirical study, Blanchflower and Burgess (1998) confirmed the positive effect of innovation on job creation in the UK industrial sector. Based on empirical evidence, several authors have identified that innovation increases not only productivity but generate employment growth (Evangelista and Vezzani, 2012; Benavente et al., 2011; Lachenmaier and Rottmann, 2011) mainly by product innovation. On the whole, employment growth is significantly higher for product innovators than for process innovators only (Harrison and al., 2014). This increase is associated with the creation of new services and products that give a competitive advantage to the innovative industrial companies. As a result, innovation generates new occupations for the STEM workforce, but these occupations need a new set of emerging skills (David et al., 2001) such as interdisciplinary skills, leadership skills or communication skills (UKCES, 2015).

On the whole, despite the existing barriers of industry-university collaboration (Bruneel et al., 2010) the partnership between industrial companies and universities needs to be strengthened. As a result, this collaboration will enable an emphasis on the professional role of the engineer, one that is needed for the inevitable ongoing industrial transformation.

Conclusions

The UK needs to develop a more focused and coherent policy towards engineering education. The fact that ‘engineering’ is not well understood by society as a whole is a major hurdle that needs to be overcome. The value and excitement of engineering need to be conveyed and children need to be engaged at the earliest stage of the school curriculum. It is not about adding a subject, more a case of using engineering as a catalyst to bring together arts, humanities, science and technology.

The value of vocational education and training in engineering subjects needs to be reinforced and the university level provision needs to be delivered in an active, engaging and globally relevant way. This suggests the growth of PBL and CDIO approaches with increased involvement of industry (both big and small) and importantly a world view that promotes mobility of both students and staff to promote the exchange of ideas and approaches.

A modern day engineer is likely to be part of a multi-disciplinary, multi-cultural, globally dispersed team. With this as a given, complacency and a reliance on English as the language of the world can no longer be justified. The UK needs a plan for change and a key player in this will be the Engineering Education Research community. Taking an objective view of the landscape without bias is vital. Too often change is stifled by vested interests or a lack of willingness to accept responsibility. With good quality evidence, developed through good EER, the compelling case for change can be made.

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