The Engineering Council's influence on Building Services Engineering education and qualifications: towards an internationalist education and training model

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Abstract

A large number of Building Services Engineering (BSE) graduates from UK universities either already live and work abroad, or aspire to do so, and the destinations for such migrants are most often English-speaking countries or countries where English is commonly used in business. Academic programmes in BSE are usually professionally accredited by the Chartered Institution of Building Services Engineers (CIBSE) under licence from the Engineering Council (EC). In the common destination countries for UK BSE graduates the Washington, Sydney and Dublin Accord (WSDA) agreements prevail, meaning that there is a mutual recognition of engineering qualifications and professional accreditation of academic courses, and this facilitates international mobility.

Since it is widely accepted that buildings account for as much as 50% of greenhouse gas emissions worldwide, it could be said that there is a worldwide sustainability agenda with respect to buildings. The common factor across national boundaries is that Building Services Engineers, as central members of building design teams, must provide much of the specialist practical knowledge to enable more energy efficient buildings to be designed and constructed, and it is therefore likely that UK educated engineers will be working in far more varied overseas locations in the near future.

The main aim of the work is to synthesise an education and training model to encourage and enable international mobility of UK BSE graduates, and to carry out some evaluation of this model. This work sets out initially to question whether a UK education in BSE necessarily provides UK graduates with the best possible skillset for work abroad. The influence of the EC upon the content of BSE study programmes has been examined, and the research assesses the benefits of the EC's influence in countries with different economic and political priorities to the UK, other western economies and to the WSDA countries. Following identification and analysis of the main issues, the model was constructed and evaluations were made using semi-structured interviews.

The methodology used in this research is necessarily underpinned by a pragmatist paradigm, which has led to the use of a mixed methods blended approach. In addition to thorough review and analysis of literature, the practical methods employed include a questionnaire survey and semi-structured interviews in three phases: an exploratory phase, an in-depth analysis, and a concluding phase.

The early conclusions indicated that the EC influence upon BSE study programmes is generally regarded as necessary and beneficial, since it provides an engineering skillset that is internationally respected and recognised. There is, however, less confidence in applying this in an international arena outside of the WSDA umbrella since different parts of the world face different economic challenges, divergent societal imperatives, and diverse attitudes to sustainability and green issues. An education and training model was constructed to address these issues and, after initial testing, was found generally to be a workable proposition to enhance the international prospects of UK BSEs, and further, could be adopted in the UK under the auspices of the Degree Apprenticeship initiatives. Such a model is, however, unlikely to be adopted in many overseas locations due to differing cultural views on the value of work-based learning and apprenticeship.

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Dedication

I dedicate this work to my mother Valerie and my father Derek snr, who together taught me the value of hard work; and to my two children, Anna and Peter, who fill me with pride whenever I think of them, which is often.

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Commonly Used Abbreviations and Acronyms

Acronym/Abbreviation	Meaning
ABET	American Board for Engineering and Technology
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
APEC	Asia Pacific Economic Cooperation
APECEA	Asia Pacific Economic Cooperation Engineer Agreement
BCS	British Computer Society (Chartered Institute for IT)
BEng (Hons)	Bachelor of Engineering with Honours
BIM	Building Information Modelling
BP	Bologna Process
BSc (Hons)	Bachelor of Science with Honours
BSE	Building Services Engineering/Engineer
BTEC	Business and Technician Education Council
CEI	Council of Engineering Institutions
CEng	Chartered Engineer
CEnv	Chartered Environmentalist
CHP	Combined Heat and Power
CIBS	Chartered Institution of Building Services
CIBSE	Chartered Institution of Building Services Engineers
CIHT	Chartered Institution of Highways & Transportation
CIPHE	Chartered Institute of Plumbing & Heating Engineering
CPD	Continuing Professional Development
DA	Dublin Accord, also Degree Apprenticeship
EAB	Engineering Accreditation Board
EC	Engineering Council
ECUK	Engineering Council of the UK
EES	Electrical Engineering Services
EI	Energy Institute
ENAEE	European Network for Accreditation of Engineering Education
EngTech	Engineering Technician
ETB	Engineering Technology Board

Acronym/Abbreviation	Meaning
EU	European Union
EurIng	European Engineer
EUR-ACE	EURopean ACcredited Engineer
FdEng	Foundation degree in Engineering
FdSc	Foundation degree in Science
FEANI	European Federation of National Engineering Associations
GCE	General Certificate of Education
HE	Higher Education
HEI	Higher Education Institution
HNC	Higher National Certificate
HND	Higher National Diploma
HVAC	Heating, Ventilating and Air-conditioning
ICE	Institute of Civil Engineers
ICTTech	Information and Communications Technician
IEA	International Engineering Alliance
IEng	Incorporated Engineer
IET	Institute of Engineering Technology
IETA	International Engineering Technologist Agreement
IGEM	Institution of Gas Engineers and Managers
IHEEM	Institute of Healthcare Engineering & Estate Management
IHVE	Institution of Heating and Ventilating Engineers
IMarEST	Institute of Marine Engineering, Science and Technology
IMechE	Institute of Mechanical Engineers
InstMC	Institute of Measurement and Control
IntET	International Registers of Engineering Technologists
IntPE	International Registers of Professional Engineers
IPEA	International Professional Engineer Agreement
IOA	Institute of Acoustics
IOP	Institute of Physics
IStructE	Institution of Structural Engineers
MEng	Master of Engineering
MES	Mechanical Engineering Services
MSc	Master of Science
MSt	Master of Studies
NC	National Certificate
ND	National Diploma

Acronym/Abbreviation	Meaning
NQF	National Qualifications Framework
PEC	Professional Engineering Competency
PEI	Professional Engineering Institution
PHE	Public Health Engineering
SA	Sydney Accord
SARTOR	Standards and Routes to Registration
SME	Small and Medium-sized Enterprise
UK-SPEC	UK Standard for Professional Engineering Competence
UNEP	United Nations Environment Programme
WA	Washington Accord
WSDA	Washington, Sydney and Dublin Accords

Chapter 1 – Introduction

1.1 The Building Services Engineering discipline

The term "Building Services Engineering" (BSE) is generally accepted to refer to the equipment and systems that control the internal environment, making buildings habitable and comfortable to occupy, and supporting the requirements of industrial or commercial processes and business functions within buildings (CIBSE, 2017a). For the people living and working in buildings and the associated processes, it is vital that the BSE systems perform reliably, effectively and efficiently. It is estimated that typically between 30% and 60% of the value of any new building is accounted for by the design and installation of its services (Portman, 2014), the higher end figure representing buildings having very complex services, such as hospitals.

Building Services Engineers then are those professionals who design, install and maintain BSE systems in buildings. (In this work, the acronym BSE will be used interchangeably to refer to the Building Services Engineering discipline as well as to Building Services Engineers.) Broadly speaking such Engineers tend to specialise in one of three main areas, namely Mechanical Engineering Services (MES), consisting of heating, ventilating and air-conditioning, often termed HVAC, Electrical Engineering Services (EES), which includes lighting and power distribution, and Public Health Engineering (PHE), which centres on water supply and drainage, though there is often some cross-over between these divisions. Other specialist sub-divisions also exist, such as lifts and escalators (also known as building transportation), data and telecommunications, building environmental management (controls) and others too numerous to mention. BSEs often work with other closely allied professions such as Civil Engineers and Fire Engineers, though as the Building Information Modelling (BIM) agenda gathers pace and the necessity for sustainable and energy efficient buildings escalates, BSE consultants are increasingly finding themselves working alongside Architects at the concept stage of building design (Portman, 2014).

The term Building Services Engineering is widely used in the UK, Ireland, Canada, Australia, New Zealand and many other nations where English is spoken, as well as in countries where English is widely used in business and industry, such as many Arab states and South East Asian countries (particularly Hong Kong at present and increasingly, China). In the USA, however, the field is also known as "Architectural Engineering" and this term is gaining global popularity, particularly as the BIM agenda advances.

According to a 2013 UK government report the construction industry directly and indirectly employs around 2.93 million people in the UK, which is equivalent to about 10% of the total UK workforce (Department for Business, Innovation & Skills, 2013), though a survey report prepared for ConstructionSkills puts the number of those employed directly in construction based occupations at just under 2 million (Drever & Doyle, 2012). This survey report also affirms that 49% of the 2 million are employed in manual occupations, and a major proportion of these (11%) are building services operatives (plumbers, electricians etc.).

Among the 51% of construction employees working in non-manual occupations the report identifies “engineering technicians” and “engineering professionals”, who together make up just over 20% of the total workforce. This category includes civil and structural engineering as well as BSEs, so the figure quoted is somewhat misleading. According to the National Career’s Service there are actually only around 17,000 people working in BSE professions in the UK, and there are around 500 vacancies each year. These professionals work primarily for independent design consultancies and building services contractors, though BSEs are also employed by equipment manufacturers, local authorities, government departments and so on (National Careers Service, 2014). In addition, many educated in the UK are employed overseas.

According to an EngineeringUK 2015 report *The State of Engineering*, the construction industry contributed 6% of the UK’s total economic output (£83 billion) and employed 2.15 million people or 6.5% of the workforce. EngineeringUK further forecasts that in global terms the construction market will grow by over 70% by 2025, this growth being primarily concentrated in emerging economies (EngineeringUK, 2015).

The membership figures of the Chartered Institution of Building Services Engineers (CIBSE), which is the Professional Engineering Institution (PEI) representing the BSE industry, would appear to support the above statistic. The institution has a steadily growing membership numbering around 19,000 in 2011 (this had risen to 21,400 in 2016), with as many as one fifth of its members outside the UK (UWE, 2011). Although a large proportion of these overseas members are foreign nationals rather than UK emigrants, this statistic does underline the international nature of the industry and indeed the importance of UK engineering standards. Furthermore, the presence of the CIBSE in 94 countries worldwide verifies that UK educated BSEs are employed in any number of overseas locations (CIBSE, 2013a).

1.2 BSE education in UK

As noted above, the number of engineers working exclusively in the Building Services field is relatively low, which is perhaps surprising, considering the importance of BSE systems in modern sustainable buildings and the high financial value associated with such systems. Of those people joining the BSE profession, many tend to progress through from manual or technical occupations, while others find their way into BSE from other engineering disciplines. Because of the niche nature of the profession and its relative inconspicuousness alongside other larger construction and engineering disciplines, it is often not seen as a career choice for school leavers. Young people aspiring towards a career in engineering in the construction industry might, for example, make a fairly simple decision to read Civil Engineering at university. Much is generally known about this discipline and there are very visible, well established, and easily researched career patterns. Such a decision would be a relatively safe choice for a student, whereas to choose to study BSE might well be considered a step into the unknown. The CIBSE is well aware of this problem and has been attempting to attract more young people into the industry for decades, though with limited success. Many established BSEs would opine that, “people get into this industry by accident!” (Unattributed, 2013), and it is noted that many BSEs have either progressed into engineer roles from practical occupations like plumbing or electrical installation, or they are graduates from other branches of engineering who have found their way into BSE.

There are several further education colleges in the UK that provide specialist courses in BSE, including National Certificates (NC), National Diplomas (ND), Higher National Certificates (HNC) and Higher National Diplomas (HND). The NC is a qualification designed for people employed in industry and is expected to be studied part-time, while the ND is a more broad-based, though still highly specialised, qualification aimed at full-time students. Under the UK’s National Qualifications Framework (NQF) both are classified as level 3 qualifications, the same academic level as university entry qualifications like GCE (General Certificate of Education) A (Advanced) levels. Universities do often accept these as entry qualifications for appropriate vocationally biased courses (subject to mapping equivalent academic credit), though the usual route for students wishing to advance in the BSE field is to progress onto an HNC course, followed by an HND, at a further education college. The HNC is designated at NQF level 4 and is therefore broadly equivalent to the first year of a university degree programme, while an HND is at NQF level 5, equivalent to the second year of a degree. Usually these courses are offered on a part-time study basis to cater for those already employed in the industry.

As already observed, BSE encompasses three main specialisms: PHE, MES and EES. Further education colleges therefore generally offer versions of BSE HNCs and HND part-time courses biased towards one or more of these sub-disciplines, matching the business needs of local employers. Most HNC and HND qualifications are conferred by the Pearson-BTEC (Business and Technician Education Council) awards agency, which hosts a repository of academic credit bearing units. Colleges can choose a particular diet of units from the repository, such that when a student gains the requisite amount of academic credit, this equates to a qualification. For BSE qualifications there are a number of compulsory core units covering the essential construction and engineering fundamentals, and the college can select appropriate specialist units to bias the course towards either the PHE, Mechanical or Electrical sub-discipline. It must be stated, however, that companies specialising in PHE are quite rare and PHE courses are likewise exceptional, therefore the Mechanical and Electrical Services specialisms tend to dominate. Firms specialising in PHE work often recruit people with a background in plumbing crafts who hold mechanically biased HNC or HND BSE qualifications and, if necessary, provide extra training on the job to develop further skills in PHE.

The NC and ND qualifications are, however, specific only to the main discipline, and these have long been recognised in all branches of engineering as the standard qualifications for those entering industry as "Engineering Technicians". People holding these level 3 qualifications who can also demonstrate the appropriate professional competencies outlined in the Engineering Council's publication, *UK Standard for Professional Engineering Competence* (known commonly and hereinafter referred to as the "UK-SPEC"), can apply to be entered on the EC's national register of engineers at "EngTech" grade and they may apply to join the CIBSE or another relevant PEI as a Licentiate member (see Section 1.3 and Chapter 2 for further discussion on professional memberships and EC registration). The majority of those in the BSE industry achieving the NC or ND are, however, expected to progress onto the HNC or HND qualifications, since the industry tends to see these qualifications as standard requirements, though interestingly there is no grade of EC registration or professional membership grade linked to level 4 or 5 academic qualifications. Professionals holding these level 4 and 5 qualifications, often by virtue of their experience, may well find themselves later in their career working with high degrees of responsibility and autonomy, and they will be effectively considered as Engineers.

Since the title Engineer is not legally protected in the UK it is permissible for companies to employ any person it deems competent in an engineering role. A typical BSE in the latter part of the 20th century and early 21st century might well be a person holding an HNC or HND qualification with perhaps EngTech registration and Licentiate professional membership, though commonly no professional membership at all. Traditionally this has occurred in the BSE industry because the option to study BSE at degree level has not been (and still is not) widely available. In addition, as already mentioned, there is no professional membership grade linked to level 4 and 5 academic qualifications. Since 1997, the EC registration grades of Incorporated Engineer (IEng) and Chartered Engineer (CEng) and the corresponding grades of membership of the PEIs has required degree qualification. A bachelor's degree (NQF level 6) is required for IEng and Associate membership, while a master's degree (NQF level 7) is needed for CEng and full membership. This means that a steadily rising number of aspiring BSEs find it advantageous to study for a degree early in their career.

Bachelor's and Master's degree academic programmes in BSE are offered by a few universities in the UK, and the relatively low count of students means that the number of degree courses stays quite small. Often such courses are offered in part-time study mode, alongside traditional full-time mode, to enable professionals already working in the industry to gain a degree alongside their work commitments. Some Master's level courses are delivered using distance learning techniques to facilitate this approach. The CIBSE's general view is that BSE degree courses, since they are aimed at new recruits to the industry as well as those progressing from HNCs and HNDs, should not attempt to specialise in MES, EES or PHE, but should remain as general as possible to give students a grounding in as many of the specialist BSE areas as possible (CIBSE, 2012).

A system of professional body accreditation operates across all the engineering disciplines to ensure that college and university courses deliver the academic content and practical skills necessary to serve industry, and this also streamlines the process as graduates apply for EC registration and PEI membership. Academic programmes in BSE generally aspire towards CIBSE accreditation, though accreditation by other relevant PEIs such as the Institute of Engineering Technology (IET) and the Energy Institute (EI) is also possible, and in many cases, desirable. It is thus self-evident that the EC, via the PEIs, has a very strong influence on the content and style of all accredited engineering degree programmes in the UK.

The themes of professional memberships, engineer registration and accreditation of engineering courses are developed as this account continues in Chapter 2.

1.3 The Engineering Council, PEIs and the UK-SPEC

The Engineering Council (EC) is the main regulatory body for all engineering professions in the UK, though it also has considerable international reach as will be discussed later in this narrative. Operating under licence from the EC are 35 Professional Engineering Institutions (PEIs) representing all the varied and diverse engineering disciplines found in the modern world, of which the CIBSE is of particular interest to this research.

The EC maintains national registers of close to 250,000 engineers and technicians at four grades: Chartered Engineer (CEng), Incorporated Engineer (IEng), Engineering Technician (EngTech), and Information and Communications Technician (ICTTech). The Council is responsible for setting and maintaining "internationally recognised standards of professional competence and ethics" for these engineering professions (ECUK, 2011) and the PEIs in turn are responsible under licence for judging the competence of engineers and entering appropriately qualified persons onto the EC's official registers.

In practical terms, engineers seeking to join their relevant PEI as an Associate or Member, whilst also applying for EC registration, would typically make a single membership application to cover both processes. This application must normally satisfy two main entry criteria: specifically, an **educational requirement** and a **professional requirement** as identified in the UK-SPEC (EC, 2010). This document, originally published by the EC in 2003 (though regularly updated), details the professional standards and competencies that engineers are required to demonstrate to be entered on the EC's register. It is therefore the primary reference document used by the PEIs to make judgements when assessing applications for membership and registration. Of particular note are the statements of generic professional engineering competencies (PECs) contained within the UK-SPEC, and these detail the competencies to be demonstrated by registrants in each of the four technician and engineer grades. These serve effectively as checklists against which the PEIs can make judgements about candidates' suitability for inclusion in the EC registers, and these PECs are usually also closely linked with membership requirements of the PEI.

Key to appreciating the influence of the EC upon the content of BSE academic programmes, is the notion of universities using the UK-SPEC and the generic PEC statements as a standard for developing Bachelor's or Master's degree programmes. The PECs must, by necessity, heavily influence the overall programme outcomes and modular learning outcomes in all engineering degree programmes if such programmes are to be professionally accredited. Where a set of generic competencies applies to a range as diverse as the numerous and varied engineering professions, there will inevitably have been considerable compromise in the development of these, and this premise has therefore been explored as a prelude to assessing the effect that this has on the international mobility of UK educated graduates.

The PEC statements are reproduced in Appendix 1.

Though it is not compulsory under UK law, for career advancement (particularly when seeking work abroad) and for continuing professional development, BSEs operating at the higher levels of responsibility and expertise generally find it advantageous to become IEng or CEng registrants, and to join the CIBSE or another relevant PEI. Some electrical specialists may opt for membership of the electrical specialist PEI, the Institute of Engineering Technology (IET), while others associated with the energy management branch of BSE may join the Energy Institute (EI) and engineers working in hospital maintenance roles are often members of the Institute of Healthcare Engineering & Estate Management (IHEEM). It is not unknown for engineers to hold dual or multiple memberships.

The CIBSE and other PEIs accredit courses under licence from the EC, by arranging regular periodic quality assurance visits to each institution. Since the aforementioned UK-SPEC and its list of PECs is used when assessing candidates for PEI membership and EC registration, it follows that the UK-SPEC, particularly the generic PEC statements contained therein, is an important reference document used by PEIs when accrediting academic courses.

The EC, the PEIs and their influence on educational programmes, the courses available in the UK, academic accreditation, and the grades of PEI membership and EC registration are discussed more fully as this narrative develops in Chapter 2. In addition, the main roles, responsibilities and pertinent parts of the histories of the EC, the PEIs and the CIBSE are catalogued.

1.4 The international field

The practice of professional memberships for engineers pervades worldwide, and in many countries the term “Engineer” is protected by law and a relevant professional membership is legally enforceable, though this approach is not favoured in the UK and countries with similar engineer registration systems.

Virtually all of the UK PEIs, including the CIBSE, have significant numbers of members overseas, this according to the EC (2013) being a sign of the generally high regard held worldwide for British engineers and engineering education. The EC estimated in 2009 that as many as 25% of engineers on its register work outside the UK in around 45 countries, and somewhere between 10 – 15% of registrants are non-UK citizens. There are over 10,500 registrants in Hong Kong, more than 7,000 in North America and a similar number across Australia and New Zealand (EC, 2009). The CIBSE has around 3,500 members overseas across 94 countries, against a total worldwide membership of 21,400, and the main locations of these fits in fairly closely with the EC’s overseas profile (CIBSE, 2013a), apart from in the USA where CIBSE is not at all well represented[1].

The EC’s overseas reach and influence extends most noticeably via the Washington, Sydney and Dublin Accords (WSDAs) and the European Network for Accreditation of Engineering Education’s (ENAEE) <u>EUR</u>opean <u>AC</u>redited <u>E</u>ngineer (EUR-ACE) scheme. These Accords are international agreements which facilitate mutual recognition of engineering qualifications in member countries and the EC’s approach works well within them, though other international agreements also exist. Notwithstanding the alternatives, The WSDA and EUR-ACE agreements would appear to be the leading forces for the standardisation and mutual recognition of engineering competencies across the globe, and the list of nations subscribing to these is constantly growing. The WSDA and EUR-ACE systems are explored in some detail in Chapter 2.

The term “internationalist” is used as a broad term in the title of this thesis to describe the ability of BSEs educated and trained in the UK to work abroad in any world location. The thesis aims to develop and synthesise an education and training model for BSEs based on this ideal. As stated above, many BSEs already do live and work abroad, and there are large numbers of BSEs trained overseas who are members of the CIBSE and are EC registrants, so it could perhaps be argued that the UK BSE industry is already somewhat internationalist in its outlook.

[1] *In the USA the largest professional body representing the equivalent of Building Services Engineers is the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), which is often seen as a sister organisation to CIBSE and is likewise recognised worldwide. ASHRAE and CIBSE enjoy a close working relationship.*

However, as a working hypothesis it is suggested that the internationalist label is not necessarily an entirely comfortable fit for UK BSE education and training at present. Although many countries across the world do indeed recognise the UK's engineering education and training systems, and respect the EC and the CIBSE, there are many countries that do not. Since the EC is one of the leading signatories to the WSDA agreements and the EUR-ACE system, this does somewhat widen the UK's influence and remit, and simplifies mutual recognition of qualifications across international borders, but again, not every country in the world is a WSDA or EUR-ACE member. Why the ideal of internationalism and the mutual recognition of engineering qualifications is important is explored further as this commentary progresses.

As a corollary to the above, it is further hypothesised that a UK education and training instils a cultural viewpoint consistent with that of Western industrialised nations. Other parts of the world self-evidently have quite different socio-political agenda and dissimilar attitudes to questions of sustainable development, so it is quite valid to question whether a UK education and training provides graduates with the best possible skillset when aspiring to work overseas.

On the question of sustainable development, it is widely accepted that buildings account for as much as 50% of greenhouse gas emissions worldwide; see for example Laumer (2006), the United Nations Environment Programme (UNEP) (2009) and the Committee on Climate Change (CCC) (2013). The Kyoto Protocol of 1997 and other subsequent international agreements and treaties have made the reduction of greenhouse gases an international imperative, thus emissions from buildings routinely come under considerable scrutiny, certainly in those Western countries that are considered to be "developed", though increasingly also in second and third world economies.

To reduce greenhouse gas emissions from buildings, it would seem obvious that buildings must operate in a more energy efficient way, and this is in itself, unsurprisingly, a huge area of debate and research. Countries tend to adopt different positions and approaches to sustainability in buildings, and will prioritise the issue differently based upon local economic imperatives or other influences.

The common factor across national boundaries, however, is that BSEs and their equivalent, as central members of building design teams, are charged with providing the practical knowledge to enable more energy efficient buildings to be designed and constructed. It is also a common factor that a great number of these BSEs will have been educated under the EC, WSDA or EUR-ACE[2] regimes and thus it is legitimate to question whether this regime is producing the graduates needed in the modern world.

Again, this leads towards a perspective that an internationalist education and training model could well prove to benefit the ideal of sustainable development in the built environment in the international arena.

[2] *As discussed in Chapter 2, the EUR-ACE system has a fairly minimal reach as far as BSE education is concerned, and the EC and WSDA approaches are dominant.*

1.5 Research aim and objectives

The over-arching aim of this research is to investigate the considerable influence that the EC has on the education of BSEs and content of BSE academic programmes in the UK and worldwide, both directly and via the WSDA (and EUR-ACE) agreements. The work further assesses how progressive this influence may be, considering that such high and increasing numbers of BSEs educated under the EC and WSDA regimes work in countries with sometimes quite different approaches to sustainability, and different views on engineering competencies. The WSDA agreements between EC equivalent bodies in signatory countries across the world allow for mutual recognition of qualifications in engineering and recognition of accreditation decisions and these countries include the common destinations for UK BSE graduates.

Since BSEs are collectively charged with taking a lead role in the global imperative for energy efficient and sustainable buildings, it is a premise of this work that the synthesis of an education and training model to promote internationalism in BSE education could make a real difference, and the synthesis and evaluation of such a model constitutes the practical aspect of this work and offers a significant contribution to knowledge.

Initially then, the project focuses upon a critical review of the influence wielded by the EC upon the style and content of BSE Bachelor’s and Master’s degree level study programmes in the UK. The role of the EC and UK-SPEC in effectively imposing rules upon the PEIs for the accreditation of study programmes is explored, with particular reference to the CIBSE. Where what are in effect a set of generic rules must apply to every engineering profession, there will inevitably have been considerable compromise in the development of these. As a working hypothesis it is possible to suppose that the larger institutions such as the Institute of Mechanical Engineers (IMechE) and IET may have wielded a disproportionate amount of influence in the drawing up of the PECs. The research sets out in the early stages to investigate this and elicit views as to how representative the PEIs consider the principles of the UK-SPEC, and whether it is generally felt that this guidance helps or hinders the process of engineering education, professional membership and registration.

Subsequently the research is extended into the international field, given that the WSDA agreements are very closely related to the EC approach to enable mutual recognition of qualifications and engineering competencies. Opinions and perceptions from appropriately qualified respondents have been elicited. The view which emerges from much of the literature is that the WSDA and EC approaches are not perfect, but they are the best available at present, notwithstanding the fact that other international agreements on engineering competencies exist. A major issue is that whilst the EC approach insists upon competence in the workplace being demonstrated, in many countries academic achievement only is considered. Furthermore, a view pervades that much BSE education is extremely theoretical and often too traditional for a changing world. For example, there are several commentators who would challenge the necessity for engineers to be able to demonstrate such high levels of mathematical ability in their education, when it may serve them better to be more conversant in some of the "softer" skills as might emerge from work-based education and training (Portman, 2014). Thus, an approach grounded more on work-based learning through properly structured apprenticeship schemes is seen by some commentators as a way forward. To critically analyse these questions an education and training model encompassing internationalism and work-based learning was constructed and some evaluations were carried out using semi-structured interviews to enable conclusions to be drawn as to the validity of such an endeavour.

1.5.1 Specific objectives

The methodologies to be employed in this work must necessarily be largely qualitative, though some quantitative data has also been gathered, and a mixed methodology is employed. In summary, the data has been gleaned from review and analysis of primary and secondary literature, from an online questionnaire survey completed by appropriately qualified PEI staff members, and semi-structured interviews with key personnel in relevant PEIs, universities in the UK and abroad, and senior engineers. The research philosophy, approach and methodologies are discussed fully in Chapter 3.

The specific objectives can be broadly broken down into three main sections:

UK focus

1. Examine the development of the EC and PEIs and critically review their influence on BSE academic programmes and qualifications;
2. Investigate the introduction of the UK-SPEC and critically review the EC's approach for making judgements about the accreditation of academic programmes and registration of engineers;
3. Critically evaluate the membership details of the PEIs and critically review the EC registration grades and PEI member categories;
4. Examine how BSE study programmes are developed and the process of professional accreditation in the UK;
5. Examine the educational and professional requirements for engineers to be registered to practise in the UK and overseas;

International focus

6. Investigate and critically analyse international systems which are attempting to facilitate international transparency of engineering qualifications;

7. Compare and contrast the main systems and procedures overseas for accrediting engineering academic programmes, recognising engineering competencies and registering/licencing engineers.
8. Elicit views as to the perceived value of a UK engineering education when practising abroad;

Synthesis and testing of an education and training model

9. Elicit views about what an education and training model should encompass to facilitate internationalism in BSE education;
10. Synthesise and critically evaluate an education and training model to promote internationalism in BSE.

1.6 Structure of the thesis

The thesis comprises of seven chapters, which are consistent with the structure and storyline of the work:

- Chapter 1 introduces the project, identifies the main stakeholders, and states the main aim and specific objectives to be addressed.
- Chapter 2 explains the research field in more detail and reviews relevant literature to draw out the main themes for further investigation.
- Chapter 3 explores the available research philosophies and methodologies to complete a research project of this type, and specifies and justifies the methodologies and data collection techniques employed.
- Chapter 4 includes analyses of the data gleaned and summarises the results from the first rounds of data collection to draw out the proposition for a new education and training model.
- Chapter 5 details the new education and training model.
- Chapter 6 summarises the results from a further round of interviews to test and assess the viability of the education and training model proposed.
- Chapter 7 summarises the project, draws the main threads of argument together, suggests conclusions and proposes future work.

Chapter 2 – Literature Review and Initial Findings

2.1 The EC, SARTOR and the UK-SPEC

The history of the formation of the EC is recorded in detail in "A Chronicle of the Engineering Council" (Chapman & Levy, 2004), and this work is summarised in the following paragraphs in order to contextualise ongoing discussions.

In the latter half of the twentieth century there was a perception that engineering occupations were becoming more and more specialised, and thus the number of professional engineering societies and institutions continued to grow steadily. By the mid-1950s the need for a central representative body for the various engineering professions became apparent, so that common standards for professional engineers and standards for education and training could be agreed. The Joint Council of Engineering Institutions was eventually formed in 1964, and in due course this became known simply as the Council of Engineering Institutions (CEI).

Later, a Royal Commission looked at the organisation and utilisation of engineering professions across the country. The central recommendation of the 1980 Finniston Report commissioned by the government was that a central engineering authority was needed to act as "an engine of change" and "to advance education in, and to promote the science and practice of engineering" in the UK (ETB, 2003). Thus, the Engineering Council, in a form similar to how it exists today, was established in 1982. This national body was to be charged with the promotion of engineering professions and the establishment of uniform standards in engineering qualifications.

As part of its mission to establish standards, the new body published the *Standards and Routes to Registration* (SARTOR) guidance document in 1985, which sets out the educational and professional standards required for the various grades of engineer (ECUK, 1985). The EC further established an auditing role to assess the ability of the PEIs to maintain registration standards. Literature published by the EC records, however, that this period was marked by an increasing dissatisfaction of the PEIs and with the unrepresentative nature of the Council's governing body, and there were also concerns about overlaps of responsibility between the PEIs and the Council. This led to root and branch reform of the governing body of the Council in 1995, the intention being to make it more responsive to the needs of the PEIs (EC, 2011b).

This period also saw further review of education and training standards, and the SARTOR guidance document was updated with the publication of SARTOR 2 in 1990 (ECUK, 1990), and again with the publication of SARTOR 3 in 1997 (ECUK, 1997), the educational base for IEng and CEng being raised in the third edition.

It is pertinent to mention here the ECs role as the UK's signatory to two important international agreements for the mutual recognition of engineering qualifications:

- The Washington, Sydney and Dublin Accords (WSDAs) operate worldwide and provide a mechanism for mutual recognition of accreditation processes and, by extension, of accredited academic qualifications (EC, 2014). The first of these agreements to come into force was the Washington Accord in 1989, to which the ECUK was a lead signatory (IEA, 2017a).

- Within Europe, the afore-mentioned ENAEE administers the EUR-ACE framework, this being a European quality mark demonstrating the international standing of academic qualifications (EC, 2014). This agreement arose under the auspices of the Bologna Process (BP) which commenced in 1999, an international agreement promoting harmonisation of all higher education (HE) qualifications across Europe, of which the UK was one of the four instigating countries. (FEANI, 2013).

Although reference to these international agreements is relevant to the present discussion, they are explored in more depth in Section 2.8.

Thus, it was in the context of these international agreements that the ECUK continually examined engineering standards during this period in its desire to maintain and promote worldwide recognition of UK engineering qualifications, while looking towards international transparency and harmonisation of qualifications (Levy, 2000). Although SARTOR 3 predates the BP by two years, the ECUK recognised the prominence of the European Engineer (EurIng) title introduced by the European Federation of National Engineering Associations (FEANI) in 1994, a European qualification broadly equivalent to CEng, which required a Master's level degree to fulfil its educational requirement. Under SARTOR and SARTOR 2 a Bachelor's degree sufficed for CEng, thus there was a mismatch. To maintain the UK's high international standing in engineering education, alongside the ideal of facilitating eventual international harmonisation of qualifications and standards, the EC set similar educational requirements for the CEng grade in SARTOR 3 (ECUK, 1997).

Continuing concerns about the increasingly broad remit and activities of the EC led to further review in 2001, and subsequently the body was split into the Engineering Technology Board (ETB) and the Engineering Council UK (ECUK) in 2002. The ETB, these days known simply as "EngineeringUK", exists as a non-profit organisation whose main role is to promote careers in engineering to young people and school leavers. The ECUK, however, retained responsibility for professional registration standards, which it reviewed once again in 2003 with the publication of the first edition of the afore-mentioned UK-SPEC, which superseded SARTOR 3. The UK-SPEC remains current and is regularly updated, edition 3 being the most recent version, and is the key document detailing the professional standards and competencies required for engineers to be entered on the Register of UK Engineers (EC, 2010). It is therefore utilised by the PEIs as the primary reference document to make judgements on admitting engineers to the register and for accrediting engineering academic study programmes. Its' standards and the professional engineering competencies (PECs) detailed therein are also used as the benchmark by educational institutions when developing academic programmes in engineering.

Since the three editions of SARTOR, followed by the UK-SPEC were all published within a relatively short time span of some 18 years, this has sometimes led to confusion (among PEIs as well as engineers) about which qualifications should be accepted as the educational base for IEng and CEng registration. A situation exists today where the academic qualification held by one engineer may be recognised differently for registration purposes than the same qualification held by another engineer due to the date the qualification was achieved (Levy, 2000). For example, until 1996 an accredited BEng (Hons) degree would have been accepted as satisfying the educational requirement for CEng registration, whereas after 1997, exactly the same degree would only fulfil the educational requirement for IEng registration, and an MEng degree or BEng (Hons) plus further learning (usually an MSc degree) would be henceforth needed for CEng registration.

The modern EC is governed by a Board of Trustees, which has 15 members representing the 35 PEIs, and a further 7 appointed by EngineeringUK. However, much of the Council's day to day work is implemented through fairly complex systems of committees and specialist panels, which elicit representation from the engineering professions through a combination of volunteer members and PEI employees. Due to the huge disparity in sizes of the PEIs there is considerable imbalance in the number of employees and volunteer representatives available to each PEI and the smaller institutions naturally tend to rely more heavily upon volunteer members carrying out some of the day to day roles. The larger PEIs can naturally afford to employ more salaried staff and accordingly it could be hypothesised that they tend to wield more influence on EC policy.

The EC also maintains a system of partners to assist in formulating policy, the full details of which lie outside the scope of this work, but Figure 1 below summarises the structure of this for the sake of completeness.

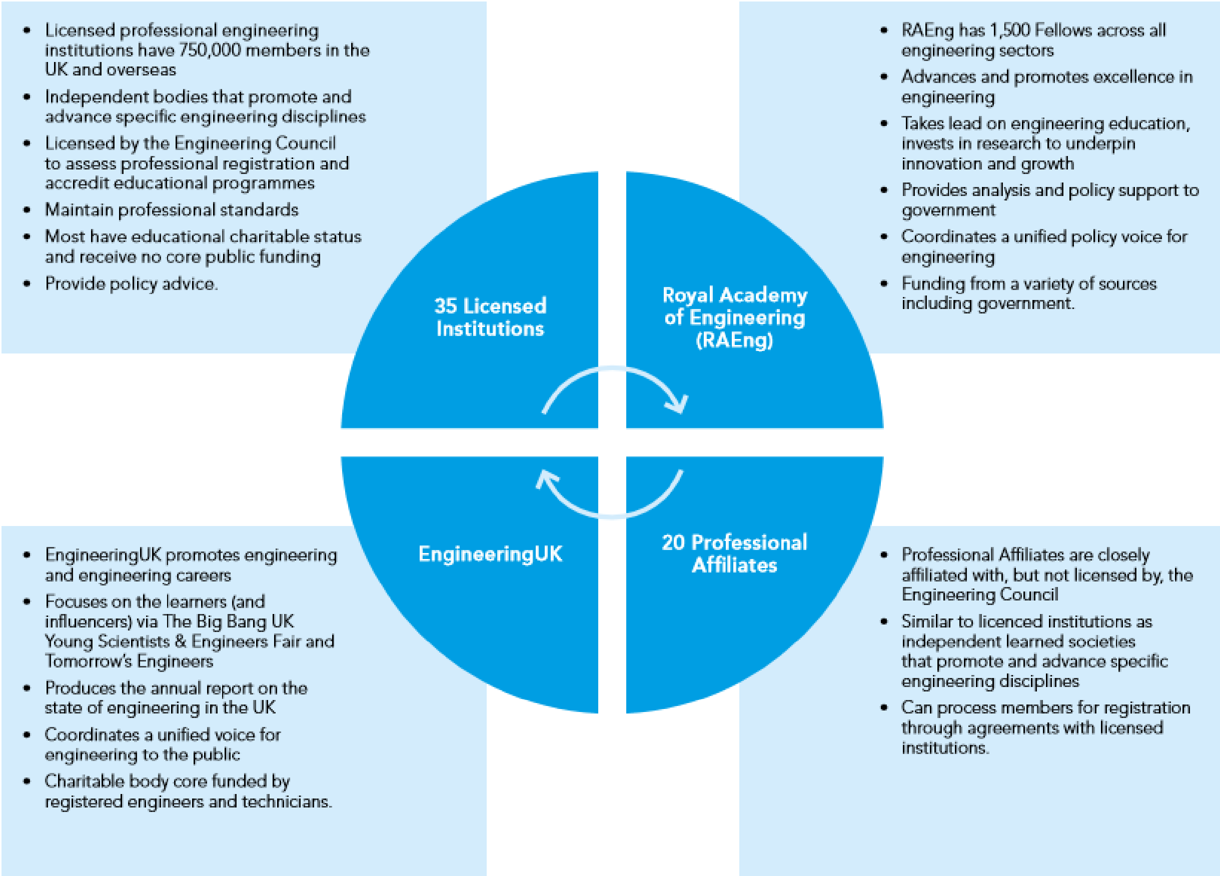

Figure 1 The EC's Partners

[source (EC, 2016)]

2.2 The EC and the PEIs

The ECUK reverted to the form "Engineering Council" in 2009, the name by which it is now known, to reflect its "growing international reach and influence" (EC, 2009). One of the principal deciding factors for so doing, contends the EC, is that the grades, CEng, IEng and EngTech have become internationally recognised standards of competence in an increasingly globalised economy (EC, 2009). In addition, this move concluded a period of intense upheaval as the ECUK struggled to assimilate the views and aspirations of the larger and more influential PEIs, and this complex and quite painful transition is related by Ramsay (2012).

The Council in its current form, operating with the authority of Royal Charter, discharges its duty of "setting and maintaining internationally recognised standards of professional competence and ethics for engineers" through the 35 PEIs, who it licenses to carry out activities relevant to the particular branch of engineering each represents. Thus, the PEIs are charged with assessing candidates for inclusion on the EC's national registers of engineers and technicians, and the PEIs also accredit academic programmes relevant to their respective engineering discipline. The licenced PEIs are all members of the Engineering Accreditation Board (EAB), a standing committee administered by the EC that has responsibility for the accreditation of academic programmes.

Membership of the licensed PEIs is normally available in the grades shown in Table 1 below, though as the table details, not all PEIs are licensed to register engineers/technicians at all grades.

Table 1 EC licenced PEIs

[sources: (EC, 2016) and questionnaire survey]

PEI	Acronym	Licensed to assess	Approx. worldwide membership	EC registrant member numbers					% of total membership with EC registration grades
				EngTech	IEng	CEng	ICTTech	Total EC registrants	
The Chartered Institute for IT	BCS	*CEng, IEng*	*75,000*		*169*	*5,488*		5,657	7.5%
British Institute of Non-Destructive Testing	BINDT	*CEng, IEng, EngTech*	*1,700*	*348*	*217*	*110*		675	39.7%
Chartered Institution of Building Services Engineers	CIBSE	*CEng, IEng, EngTech*	*21,400*	*694*	*1,158*	*5,984*		7,836	37.3%
Chartered Institution of Highways & Transportation	CIHT	*CEng, IEng*	*13,500*	*39*	*215*	*592*		846	6.3%
Chartered Institute of Plumbing and Heating Engineering	CIPHE	*IEng, EngTech*	*7,500*	*948*	*112*			1,060	14.1%
Chartered Institution of Water and Environmental Management	CIWEM	*CEng, IEng, EngTech*	*9,000*	*13*	*225*	*812*		1,050	11.7%
Energy Institute	EI	*CEng, IEng, EngTech*	*22,000*	*26*	*139*	*1,831*		1,996	9.1%
Institution of Agricultural Engineers	IAgrE	*CEng, IEng, EngTech*	*3,000*	*291*	*169*	*185*		645	21.5%
Institution of Civil Engineers	ICE	*CEng, IEng, EngTech*	*85,000*	*1,113*	*2,695*	*35,679*		39,487	46.5%
Institution of Chemical Engineers	IChemE	*CEng, IEng, EngTech*	*44,000*	*23*	*52*	*11,155*		11,230	25.5%
Institute of Cast Metals Engineers	ICME	*CEng, IEng, EngTech*	*1,000*	*27*	*73*	*64*		164	16.4%
Institution of Engineering Designers	IED	*CEng, IEng, EngTech*	*5000*	*97*	*834*	*362*		1,293	25.9%
Institution of Engineering and Technology	IET	*CEng, IEng, EngTech, ICTTech*	*163,000*	*4,121*	*12,083*	*44,994*	195	61,393	37.5%
Institution of Fire Engineers	IFE	*CEng, IEng, EngTech*	*10,000*	*184*	*22*	*236*		442	4.4%

PEI	Acronym	Licensed to assess	Approx. worldwide membership	EC registrant member numbers					% of total membership with EC registration grades
				EngTech	IEng	CEng	ICTTech	Total EC registrants	
Institution of Gas Engineers and Managers	IGEM	*CEng, IEng, EngTech*	*4,000*	*448*	*484*	*1,219*		2,151	53.8%
Institute of Highway Engineers	IHE	*CEng, IEng, EngTech*	*3,250*	*224*	*941*	*30*		1,195	36.8%
Institute of Healthcare Engineering & Estate Management	IHEEM	*CEng, IEng, EngTech*	*1,700*	*88*	*323*	*128*		539	31.7%
Institution of Lighting Professionals	ILP	*CEng, IEng, EngTech*	*2,100*	*114*	*271*	*60*		445	21.2%
Institute of Marine Engineering, Science and Technology	IMarEST	*CEng, IEng, EngTech*	*17,000*	*451*	*2,080*	*4,675*		7,206	42.4%
Institution of Mechanical Engineers	IMechE	*CEng, IEng, EngTech*	*111,000*	*1,754*	*1,495*	*38,595*		41,844	37.7%
Institute of Measurement and Control	InstMC	*CEng, IEng, EngTech*	*3,500*	*41*	*416*	*1,386*		1,843	52.7%
Institution of Royal Engineers	InstRE	*CEng, IEng, EngTech*	*12,000*	*664*	*27*	*15*		706	5.9%
Institute of Acoustics	IOA	*CEng, IEng*	*3,000*		*16*	*183*		199	6.6%
Institute of Materials, Minerals and Mining	IOM3	*CEng, IEng, EngTech*	*18,000*	*83*	*422*	*5,499*		6,004	33.4%
Institute of Physics	IOP	*CEng*	*50,000*			*716*		716	1.4%
Institute of Physics & Engineering in Medicine	IPEM	*CEng, IEng, EngTech*	*4,200*	*12*	*24*	*79*		115	2.7%
Institution of Railway Signal Engineers	IRSE	*CEng, IEng, EngTech*	*5,400*	*21*	*36*	*70*		127	2.4%
Institution of Structural Engineers	IStructE	*CEng, IEng, EngTech*	*27,000*	*114*	*967*	*9,052*		10,133	37.5%
Institute of Water	IWater	*CEng, IEng, EngTech*	*2,000*	*45*	*195*	*23*		263	13.2%
Nuclear Institute	NI	*CEng, IEng, EngTech*	*3,000*	*8*	*75*	*225*		308	10.3%
Royal Aeronautical Society	RAeS	*CEng, IEng, EngTech*	*21,000*	*190*	*728*	*3,396*		4,314	20.5%

PEI	Acronym	Licensed to assess	Approx. worldwide membership	EC registrant member numbers					% of total membership with EC registration grades
				EngTech	IEng	CEng	ICTTech	Total EC registrants	
Royal Institution of Naval Architects	RINA	*CEng, IEng, EngTech*	*10,000*	*13*	*110*	*2,119*		2,242	22.4%
Society of Environmental Engineers	SEE	*CEng, IEng, EngTech*	*750*	*10*	*18*	*136*		164	21.9%
Society of Operations Engineers	SOE	*CEng, IEng, EngTech*	*14,500*	*2,677*	*2,216*	*814*		5,707	39.4%
The Welding Institute	TWI	*CEng, IEng, EngTech*	*5,000*	*974*	*279*	*448*		1701	34.0%
		TOTALS	**779,100**	**15,855**	**29,286**	**176,360**	**195**	**221,501**	**28.5%**

Leading on from the data presented above it is helpful to investigate the detail about the membership profile of the PEIs that are the most significant to this work with a more nuanced approach. Of particular interest to this discussion are the relative sizes of the institutions in terms of individual members, and numbers of members at grades commensurate with EC registration as opposed to “non-engineer” membership grades.

For the purposes of this work, institutions have been categorised as small, medium-sized and large according to the number of members at all grades:

- Small institutions are those with fewer than 10,000 members, of which there are 20;
- Medium-sized institutions are those with between 10,000 and 50,000 members, of which there are 11;
- Large institutions are those with more than 50,000 members, and there are four.

It can, however, be seen that not all the institutions have engineering as their only business, good examples of this being the BCS with 75,000 members, of whom only 5,657 are engineers, and the IOP with just 716 engineer members from a total membership of 5,000. It is therefore useful in this work to consider the number of members of each PEI who have a membership category commensurate with EC registration. Three categories in respect of engineer member numbers were defined:

- Small PEIs with less than 5,000 engineer members, of which there are 25;
- Medium-sized PEIs with 5,000 – 25,000 engineer members, of which there are 7;
- Large PEIs with more than 25,000 such members, of which there are three.

The largest PEI by far in terms of individual membership is the IET, with around 163,000 members worldwide, followed by the Institute of Mechanical Engineers (IMechE) with 111,000 members, the Institute of Civil Engineers (ICE) with 85,000, and the Chartered Institute for IT (until recently known as the British Computer Society, hence the acronym BCS) with 75,000. The CIBSE can be classified as a middle-sized PEI, claiming 21,400 individual members worldwide, along with bodies like the Institution of Structural Engineers (IStructE) with 27,000 members and the Energy Institute (EI) with 22,000.

As indicated in Table 1, the PEIs are not all licensed to assess engineers for registration at all grades. For instance, the Chartered Institute of Plumbing & Heating Engineering (CIPHE) is licensed to assess only at EngTech and IEng levels, which is consistent with its recent history as primarily a craft and technician based institution (the Institution of Plumbing and Heating Engineering gained its royal charter to become the CIPHE as recently 2008). Conversely, the Institute of Physics (IOP) is only licensed to assess Chartered Engineers, while the Chartered Institute for IT (BCS), Institute of Acoustics (IOA) and the Chartered Institution of Highways & Transportation (CIHT) may assess Incorporated and Chartered Engineers, but not Technicians. Interestingly, the only PEI licensed to assess ICT Technicians is the IET, where one might reasonably expect that the BCS would fulfil this function, though this discussion is outside the scope of this work.

Total membership numbers and engineer member numbers do not provide a full representation, however, and the full picture is complex. All of the PEIs offer grades of individual membership that are not associated with EC registration, and in some PEIs, many of these members specialise in disciplines related to, but outside of, engineering. Some of the PEIs also offer alternative professional membership grades that are not at all commensurate with EC registration; for example, the IET and CIPHE have grades to attract practising craft operatives and installers, the IOP has far more members who are Chartered Physicists than it has Chartered Engineers, and the EI has many more Chartered Environmentalists (CEnv) than it has Engineers. Of those PEI members who are engineering specialists, a large (though difficult to quantify) number are student and graduate affiliates, of whom the PEIs would wish the majority to progress eventually to a professional membership grade. All the PEIs also allow professional affiliate and companion memberships for people working in non-engineering capacities, but who are associated with the particular area of engineering the PEI represents, though these numbers are small.

For the purpose of this research, which focuses on the engineering disciplines and BSE in particular, it is advantageous to consider the number of EC registrant member grades expressed as a percentage of total membership. The larger PEIs and the very small specialist PEIs tend to top this list. The highest percentages of EC registrants are the Institution of Gas Engineers and Managers (IGEM) and the Institute of Measurement and Control (InstMC) with 53.8% of 4,000 members and 52.7% of 3,500 members respectively. In these smaller PEIs, the percentage of engineer grade membership tends to be high primarily because the institutions are highly specialist and consequently tend to attract only very highly qualified members. Among the larger PEIs the highest percentage of engineering registrants are the ICE with 46.5% of its 85,000 members, the IET with 37.5% of 163,000, and the IMechE with 37.7% of 111,000. The CIBSE compares favourably with these institutions with 37.3% of its membership being EC registrants, though the medium-sized PEI with the highest ratio is the Institute of Marine Engineering, Science and Technology (IMarEST) with 42.4% of its 15,000 members being EC at registrant grades. The IET, despite offering membership in non-engineer grades (for practising electrical installers) is well represented, while the CIPHE (which attracts plumbing and heating installers), being one of the smaller middle-sized PEIs with 7,500 members, has just 14.1% of its membership at EC registrant grades. Also worthy of note is that the EI, which tends to attract facilities and building maintenance managers has only 9.1% of its 22,000 strong membership at engineer grades, reflecting the fact that such managers are rarely engineers, though many are CEnv registrants.

As has previously been described, virtually all the PEIs have significant numbers of members outside the UK, this according to the EC (2013) being a sign of the generally high regard held worldwide for British engineers and engineering education. The EC estimated in 2009 that as many as 25% of engineers on the Council's register work outside the UK in around 45 countries, and somewhere between 10 – 15% of registrants are non-UK citizens. There are over 10,500 registrants in Hong Kong, more than 7,000 in North America and a similar number across Australia and New Zealand (EC, 2009).

2.3 The CIBSE

The CIBSE, based in London, is recognised worldwide as an international professional body representing the BSE profession, it is a licenced EC PEI, and is a full member of the Construction Industry Council in the UK, meaning that it is consulted by the government on matters relating to construction and engineering. The institution's origins date back to the latter years of the Victorian Era when technical solutions to building comfort first began to emerge, and the Institution of Heating and Ventilating Engineers (IHVE) was founded in 1897. By Royal Charter, the IHVE and the Illuminating Engineering Society were amalgamated in 1976, forming the Chartered Institution of Building Services (CIBS). The word "Engineers" was later added in 1985 shortly after the EC was formed and the institution was recognised as a PEI.

The CIBSE's objective defined in its Royal Charter is to "support the science, art and practice of building services engineering" and it undertakes to accomplish this by providing "first class information and education services" (CIBSE, 2017a). To this end the institution aims to promote competence through education, training and EC registration, and delivering up-to-date knowledge in BSE related matters through its membership networks, publications and research. The CIBSE professes to focus both on the engineering and the construction sectors of the economy, and strives to promotes a multi-disciplinary ethos to construction and provide a co-ordinating role for the application of scientific and engineering principles in buildings (CIBSE, 2011).

The CIBSE claims a world-wide membership of around 21,400 individuals, which makes it the eighth largest of the PEIs, though it comes within the medium-sized bracket. Around 3,500 members of CIBSE are based overseas across 94 countries, and the main locations of these fits in fairly closely with the EC's overseas profile (CIBSE, 2013a), apart from in the USA where CIBSE is not at all well represented. The professional body representing BSEs in the USA is the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), which is often seen as a sister organisation to CIBSE and is likewise recognised worldwide. A recent study carried out at the University of the West of England (2011) details that the vast majority of CIBSE's overseas members are in non-European locations. CIBSE's worldwide presence can further be verified by the fact that there are, in addition to the 16 UK regional branches, three overseas branches: in the Republic of Ireland, in Hong Kong, and one branch representing both Australia and New Zealand, and there are also Country Representatives in Sri Lanka, the United Arab Emirates, South Africa, Qatar, Bahrain, Thailand, Singapore, China and Canada (CIBSE, 2013a). The Hong Kong Region is the largest of the overseas CIBSE branches with over 2,700 members and this region continues to grow. The Australia and New Zealand Region has a relatively small membership of around 750, though covers a vast area. It is therefore divided into six Australian chapters, one representing each state, and two New Zealand chapters representing Christchurch and Wellington respectively (CIBSE, 2013b). CIBSE Ireland, based in Dublin, currently has just over 700 members.

Despite its modest size, CIBSE is a body that is seen in engineering circles as consistently "punching above its weight". Andrew Ramsay, a staff member, Secretary and CEO of the CIBSE from 1979, joined the EC as Director for Engineers Regulation in 1997 and rose to become the EC's CEO in 2002, where he stayed until 2010. He recollects: "My entry in 1979 into the professional staff community was in building services engineering – an obscure discipline even to other engineers" (Ramsay, 2010). He further recounts that CIBSE was characterised as a campaigning institution: "Long used to underdog status, the institution had taken on ministers, lawmakers, the Privy Council and the engineering establishment – and generally won" (Ramsay, 2010). The very significant campaign in CIBSE's history, in which Ramsay was instrumental, was to gain CEng recognition for the core of the BSE profession in the period leading up to SARTOR 3, many of whom for reasons previously discussed, did not hold degree level academic qualifications (Ramsay, 2012).

A large part of CIBSE's work is in the publication of a series of BSE Design Guides and Technical Memoranda, which are utilised worldwide by engineers and construction professionals. Some of the design criteria published in CIBSE Guides are cited in UK Building Regulations which therefore makes them legislative requirements for building works.

Table 2 below summarises the undergraduate degree courses currently available in the UK which are accredited by the CIBSE.

Table 2 Accredited undergraduate BSE study programmes

[source: EC (2017a)]

***(Key to abbreviations used:** BEng (Hons) – Bachelor of Engineering with Honours, BSc (Hons) – Bachelor of Science with Honours, MEng – Master of Engineering, FdSc – Foundation degree of Science, FdEng – Foundation degree of Engineering, FT – full-time, PT – part-time)*

Institution	Degree	Course title	Study mode	Accreditation status
Coventry University	BEng (Hons)	Building Services Engineering	FT & PT	IEng fully CEng partially
Glasgow Caledonian University	BEng (Hons)	Building Services Engineering	PT	IEng fully CEng partially
	BSc (Hons)	Building Services Engineering	PT	IEng fully
Heriot-Watt University	MEng	Architectural Engineering	FT	CEng fully
	BEng (Hons)	Architectural Engineering	FT	IEng fully CEng partially
University of Central Lancashire	BEng (Hons)	Building Services and Sustainable Engineering	FT & PT	IEng fully CEng partially
Liverpool John Moores University	MEng	Building Services Engineering	FT & PT	CEng fully
	BEng (Hons)	Building Services Engineering	FT & PT	IEng fully CEng partially
	BSc (Hons)	Building Services Engineering Project Management	FT & PT	IEng fully
	FdSc	Building Services Engineering	FT & PT	IEng partially
London South Bank University	BEng (Hons)	Building Services Engineering	FT & PT	IEng fully CEng partially
	BSc (Hons)	Building Services Engineering	FT & PT	IEng fully
	FdEng	Building Services Engineering	FT & PT	IEng partially
	HND	Building Services Engineering	FT & PT	IEng partially
Northumbria University	MEng	Building Services Engineering	FT & PT	CEng fully
	BEng (Hons)	Building Services Engineering	FT & PT	IEng fully CEng partially
	FdSc	Building Services Engineering	PT	IEng partially
University of Nottingham	MEng	Architectural Environment Engineering	FT	CEng fully
	BEng (Hons)	Architectural Environment Engineering	FT	IEng fully CEng partially
University of Ulster	MEng	Energy and Building Services Engineering	FT & PT	CEng fully
	BEng (Hons)	Energy and Building Services Engineering	FT & PT	IEng fully CEng partially
University of the West of England	BEng (Hons)	Architecture and Environmental Engineering	FT	IEng fully CEng partially

It will be noted here that the only undergraduate degrees accredited for full CEng registration and PEI Member status are MEng degrees. Many of the institutions offer BEng degrees which are accredited as fully meeting the educational requirements for IEng and Associate membership, while partially fulfilling the requirements for CEng and full PEI membership. Therefore, several accredited post-graduate degrees exist, referred to as “further learning”, which, when studied following an accredited BEng, fulfil the educational requirement for CEng registration and full PEI Membership. Table 3 below summarises these.

Table 3 Accredited post-graduate BSE study programmes

[source: EC (2017a)]

*(**Key to abbreviations used:** MSc – Master of Science, MSt – Master of Studies, DL – distance learning)*

Institution	Degree	Course title	Study mode	Accreditation type
Brunel University	MSc	Building Services Engineering Building Services Engineering with Sustainable Energy Building Services Engineering Management Sustainable Energy, Technologies and Management	FT, PT & DL	CEng
Cambridge University	MSt	Interdisciplinary Design in the Built Environment	PT	CEng
De Montfort University	MSc	Climate Change and Sustainable Development Energy and Industrial Sustainability Energy and Sustainable Building Design	FT, PT & DL	CEng
Glasgow Caledonian University	MSc	Building Services Engineering Energy and Environmental Management Waste Management Sustainable Energy Technology	FT, PT & DL FT & PT	CEng
Heriot-Watt University	MSc	Architectural Engineering	FT, PT & DL	CEng
Imperial College London	MSc	Systems Engineering and Innovation	FT	CEng
London South Bank University	MSc	Building Services Engineering Environmental and Architectural Acoustics Sustainable Energy Systems	FT, PT & DL FT & PT FT & PT	CEng
Loughborough University	MSc	Building Services Engineering Low Carbon Building Design and Modelling	FT & PT	CEng
University of Nottingham	MSc	Energy Conversion and Management Sustainable Building Technology	FT & PT	CEng
University of Central Lancashire	MSc	Building Services	FT & PT	CEng
University College London	MSc	Environmental Design and Engineering Light and Lighting	FT & PT	CEng
University of Ulster	MSc	Renewable Energy and Energy Management	PT & DL	CEng

2.4 EC registration and professional membership

As previously related, today's EC maintains national registers of engineers and technicians at the four grades of CEng, IEng, EngTech and ICTTech, and the PEIs offer grades of membership commensurate with these. The main attributes and headline specific competencies linked with each registration grade are listed in Table 4 below.

Table 4 Technician and Engineer registration grades summary

[source: EC (2016)]

Grade	Description	Headline specific competencies
Engineering Technician (EngTech)	Engineering Technicians apply proven techniques and procedures to the solution of practical engineering problems.	Engineering Technicians are required to apply safe systems of work and are able to demonstrate: • Evidence of their contribution to either the design, development, manufacture, commissioning, decommissioning, operation or maintenance of products, equipment, processes or services • Supervisory or technical responsibility • Effective interpersonal skills in communicating technical matters • Commitment to professional engineering values
Incorporated Engineer (IEng)	Incorporated Engineers maintain and manage applications of current and developing technology, and may undertake engineering design, development, manufacture, construction and operation.	Incorporated Engineers are able to demonstrate: • The theoretical knowledge to solve problems in developed technologies using well proven analytical techniques • Successful application of their knowledge to deliver engineering projects or services using established technologies and methods • Responsibility for project and financial planning and management together with some responsibility for leading and developing other professional staff • Effective interpersonal skills in communicating technical matters • Commitment to professional engineering values.

Grade	Description	Headline specific competencies
Chartered Engineer (CEng)	Chartered Engineers develop solutions to engineering problems using new or existing technologies, through innovation, creativity and change and/or they may have technical accountability for complex systems with significant levels of risk.	Chartered Engineers are able to demonstrate: • The theoretical knowledge to solve problems in new technologies and develop new analytical techniques • Successful application of the knowledge to deliver innovative products and services and/or take technical responsibility for complex engineering systems • Accountability for project, finance and personnel management and managing trade-offs between technical and socio-economic factors • Skill sets necessary to develop other technical staff • Effective interpersonal skills in communicating technical matters.
ICT Technician (ICTTech)	Professionally registered Information and Communications Technology Technicians work in a variety of environments. These include, but are not limited to: offices, development labs, data and operational centres, field environments, customer premises and manufacturing.	ICT Technicians support a range of functions which utilise ICT solutions, and hardware and software components. Examples of functions include, but are not limited to: design, development, implementation, installation, operation, problem solving and security of ICT applications, products, services and/or infrastructures.

As has been previously indicated, the granting of PEI membership and the corresponding grade of EC registration depends upon candidates satisfying two main requirements: an **educational component** alongside a **professional component**. An academic qualification from an accredited course of study satisfies the educational requirement neatly (though non-accredited qualifications can also be considered on a case by case basis), and there is further discussion about academic programmes in Section 2.4.3 below. After achieving the requisite academic qualification, engineers must then demonstrate competency against the PEC statements detailed in the UK-SPEC (EC, 2010).

The PECs for the three grades of Engineer registration are set out in five main professional areas.

A. Engineering knowledge
B. Engineering practice
C. Personal responsibility
D. Interpersonal skills
E. Professional conduct and standards

For each of these professional areas a general statement is attached as shown in Table 5 below[3]. These are shown side by side in Table 5 to enable ready comparison, but in the UK-SPEC they are shown separately for each Engineer grade alongside lists of specific competencies against pertaining to each of the general statements. These, being too lengthy to reproduce here, are shown in full in Appendix 1.

Table 5 Summary of general statements of professional competence for engineer grades

[source: EC (2010)]

Professional area	**Registration category**		
	EngTech	**IEng**	**CEng**
A. Engineering knowledge	Use engineering knowledge and understanding to apply technical and practical skills.	Use a combination of general and specialist engineering knowledge and understanding to apply existing and emerging technology.	Use a combination of general and specialist engineering knowledge and understanding to apply existing and emerging technology.
B. Engineering practice	Contribute to the design, development, manufacture, construction, commissioning, operation or maintenance of products, equipment, processes, systems or services.	Apply appropriate theoretical and practical methods to design, develop, manufacture, construct, commission, operate, maintain, decommission and re-cycle engineering processes, systems, services and products.	Apply appropriate theoretical and practical methods to the analysis and solution of engineering problems.
C. Personal responsibility	Accept and exercise personal responsibility.	Provide technical and commercial management.	Provide technical and commercial leadership.
D. Interpersonal skills	Use effective communication and interpersonal skills.	Demonstrate effective interpersonal skills.	Demonstrate effective interpersonal skills.
E. Professional conduct and standards	Make a personal commitment to an appropriate code of professional conduct, recognising obligations to society, the profession and the environment.	Demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment.	Demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment.

The PEC statements are by necessity very generic since they must apply equally to, and be capable of interpretation by, all engineering disciplines, such that they can be used as a checklist when assessing applications for membership and registration. Depending upon the applications procedures for each PEI (which differ only very slightly), candidates for CEng and IEng and the corresponding membership grades must supply evidence (usually in the form of a written report) as to how they have met the defined competencies along with verification of their academic qualification. The final part of the applications

[3] *The detailed competencies for ICTTech are not shown as these are not relevant to BSEs and therefore lie outside the scope of this work.*

process is then a professional review interview arranged by the PEI, where an expert panel questions the applicant in detail, and a judgement about the candidate's engineering competence can subsequently be reached.

Candidates may be prepared by their employer for this process by means of an in-company training scheme, which may itself be accredited by the PEI, or by means of in-company training mentors, but often engineers will find their own way through the process; they may attend membership briefing sessions run by their PEI and would often take advice from peers and more senior colleagues. This last scenario is very likely in BSE as most consultancies and contractors tend to be small and medium-sized enterprises (SMEs) and such firms are less likely to have established training managers and specialist mentors than large national companies.

Although the title Engineer is not protected under UK law, the professional titles awarded by the EC most certainly are, and the details of these registration grades are explored more fully below.

2.4.1 Chartered Engineer (CEng)

According to the EC, "Chartered Engineers develop solutions to engineering problems using new or existing technologies, through innovation, creativity and change and/or they may have technical accountability for complex systems with significant levels of risk" (EC, 2017b). It is further expected that Chartered Engineers apply theoretical knowledge to solve problems in new technologies and develop new analytical techniques, and thus, by exercising their knowledge and judgement, lead the profession (Tittagala, Hadidimoud, & Liang, 2016).

The title, Chartered Engineer, is recognised as a terminal qualification in engineering and is protected by civil law, as are the post-nominal letters, CEng, which registrants are entitled to use. The Chartered Engineer title is also recognised in European Union states in accordance with EU Directive 2005/36, and it is further recognised worldwide through various treaties and accords, in particular the afore-mentioned Washington Accord (WA).

To gain CEng registration, candidates must normally be qualified to Master's degree level in an engineering discipline, that is NQF level 7, (academic courses are discussed in Section 2.4.3 below) and be able to demonstrate the higher level professional competencies laid down in the UK-SPEC, as summarised in Table 5 above.

Typically, it can take 8 – 10 years for a young engineer to reach the CEng level of proficiency, since to do so requires at least 4 years of university study (though if studying part-time it can take 6 or even 7 years to gain the requisite academic qualification, longer if the young engineer progresses from a NC or craft qualification) followed by, typically, a minimum of 4 years post-graduate training in professional practice. In the field of BSE, since so many aspiring engineers tend to study part-time alongside employment in the industry, it is not unknown for the CIBSE to allow for some of the period of professional training in the workplace to have taken place simultaneously alongside the later stages of university education.

2.4.2 Incorporated Engineer (IEng)

The EC describes Incorporated Engineers as professionals who “maintain and manage applications of current and developing technology, and may undertake engineering design, development, manufacture, construction and operation” (EC, 2017c). In the same way as for Chartered Engineers, the Incorporated Engineer title is protected by civil law and registrants are entitled to use post-nominal letters, in this case IEng.

Incorporated Engineers are also recognised across EU nations and worldwide through the Sydney Accord (SA) and other international treaties and agreements. However, what the EC terms Incorporated Engineers are known throughout much of the world as “Engineering Technologists” (indeed the SA uses this terminology), and this etymological distinction can be cumbersome. Augusti (2009) contends that a rigid distinction between “engineers” and “technologists” can be undesirable, and is in any case a meaningless distinction in many world languages.

The registration requirements and applications process for IEng are very like those for CEng, the main difference being that candidates would spend a shorter time in education since a 3 year Bachelor’s degree (4 years in Scotland), normally a BEng at NQF level 6 is the academic requirement. IEng candidates must also demonstrate an alternative (though similar in many respects) set of professional competencies laid down in the UK-SPEC (see again Appendix 1 and Table 5 above). A key difference between engineers practising at IEng level and those working with CEng responsibilities is that the UK-SPEC stipulates that Incorporated Engineers should be able to utilise proven theoretical knowledge and analytical techniques to solve problems associated with established technologies, whereas Chartered Engineers are expected to be able to contribute towards the ongoing development of new theoretical knowledge and analytical techniques to solve problems associated with emerging technologies (Tittagala, Hadidimoud, & Liang, 2016). This distinction is reflected in the PEC statements.

In most engineering professions, Incorporated Engineers assume lesser degrees of responsibility and autonomy than Chartered Engineers and it is often argued that in the work of an Incorporated Engineer, the principles of engineering and mathematics are more applied, whereas a Chartered Engineer’s work is likely to be more abstract, theoretical and managerial. Many Incorporated Engineers would contend that this hierarchical approach is somewhat counterproductive and argue that there should be more parity of esteem with Chartered Engineers.

In BSE and many other branches of engineering IEng registration is often seen as a milestone in career progression on the way to earning CEng qualification and certainly the CEng title is very much more sought after. According to 2016 figures there are over 176,000 CEng registrations and just under 30,000 IEng registrants (EC, 2016), which represents a six-fold disparity.

2.4.3 Academic programmes for CEng and IEng registration

The academic qualifications required for CEng registration are either a 4 year MEng degree (5 years in Scotland) or a 3 year BEng (Hons) degree (4 years in Scotland) supplemented by suitable post-graduate “further learning”, usually an MSc degree, which can be taken in one full-time year or over two years part-time alongside employment. While it is certainly possible for candidates with non-accredited qualifications to be admitted to the Register, it considerably streamlines the process for candidates applying for registration if their academic qualifications are indeed accredited by the appropriate professional body. To assist HEIs to develop academic courses in engineering disciplines, and to provide them with a definitive single point of reference to meet academic and professional standards, the EC published *Accreditation of Higher Education Programmes: UK Standard for Professional Engineering Competence* (generally and hereinafter referred to as AHEP) in 2004. This publication is periodically reviewed and the most recent third edition, AHEP 3, was published in 2014 (EC, 2014).

MEng degrees are broad-based, full-time, highly vocational undergraduate programmes, focussed directly on industry requirements and engineering competencies, and are intended for more able students with higher entry qualifications. Because of the vocational nature and considerable industrial involvement in the design (and often delivery) of MEng degrees, these courses are frequently made available in sandwich or part-time attendance mode, as well as full-time. The courses are intended to provide an integrated, design biased engineering education with a strong mathematical, technological and science based foundation, though within this basic specification the content can vary according to each engineering discipline. Some courses emphasise study of a particular engineering discipline to greater depth and breadth, and indeed accredited BSE courses tend to do just this, while others offer a multidisciplinary education in a range of engineering disciplines, Mechanical Engineering being a good example of this approach. Because the PECs listed in the UK-SPEC include high level technical and commercial leadership skills, with the aim of producing more rounded engineers who might also be competent in business, courses include aspects of the commercial and managerial side of engineering. Business and commercial practices, principles of management, finance and so on are therefore taught alongside the specialist engineering subjects. Universities use the UK-SPEC, AHEP 3 and specialist advice issued by the associated PEI as guidance when designing MEng programmes and AHEP 3 in particular appears to work very effectively by providing a checklist of items that should be taught and assessed.

Built into the requirements of the UK-SPEC is an expectation for registrants to undertake regular continuing professional development (CPD) throughout their career, this being the systematic acquisition of knowledge and skills, and the development of personal qualities, to maintain and enhance professional competence. Since Chartered Engineers are effectively considered to lead the engineering professions, it can therefore be argued that the depth and breadth of education in MEng degrees and approved MSc degrees must be pitched at such a level that CPD for Chartered Engineers would occur naturally during their professional career (Tittagala, Hadidimoud, & Liang, 2016). The PEIs however, are charged with monitoring CPD during the careers of Chartered and Incorporated Engineers.

The BEng degree, which is the exemplifying academic qualification for IEng, is again a highly vocationally focussed academic programme, and is thus often made available for part-time attendance mode as well as full-time, and is usually offered with the option of an industrial sandwich placement year. Often, universities would offer the BEng and MEng as essentially the same course at levels 4 and 5, with divergences at level 6, and then the MEng has an additional year at level 7. Students graduating from the course at level 6 would be awarded the BEng (Hons) degree and those completing level 7 would get the MEng. The course structures are required to be designed by universities such that the subjects studied provide a rounded engineering education for those graduating at Bachelor's level, and provide some higher-level specialist studies at level 7 (EC, 2014). Most often there are different admissions requirements to access these courses, the higher qualified students are admitted straight to the MEng, while the lesser qualified students access the associated BEng course. During the period of study, however, there are usually opportunities for BEng students to transfer onto the MEng route by demonstrating good academic performance. See Section 2.6 for further discussions on the design of academic courses in BSE. For students who do not have the opportunity to access an MEng course or do not meet the entry requirements, the alternative academic qualification for CEng registration is a BEng (Hons) degree followed by a period of recognised postgraduate further learning, usually consisting of an accredited MSc degree. There is a distinct difference between MEng undergraduate programmes and taught post-graduate MSc courses. While the MEng is intended as a broad based integrated course as described above, most MSc courses tend to involve in-depth study of specialised areas. MSc and MEng programmes do not therefore duplicate one another, though they are not mutually exclusive (see Section 2.6 for further discussions on this subject).

All engineering programmes are validated under the UK's academic-credit based system as indicated in Figure 2 below, where 120 credits are delivered each academic year on full-time courses, such that 360 credits equates to a three year bachelor's degree, while 480 credits delivered over four years is required for the award of an undergraduate master's degree. As mentioned previously, the three or four years of study may be extended to facilitate part-time delivery alongside employment. Typically 80 credits are delivered per year in part-time study mode, meaning that it takes 6 years to complete an MEng degree part-time and

5 years to complete a BEng (Hons). An MSc course, since it comprises 180 academic credits, is usually delivered in one extended academic year full-time, or over two years part-time.

Academic courses providing the educational requirement for the EngTech grade are at NQF level 3 and are delivered in further education colleges, and are therefore outside the scope of this work.

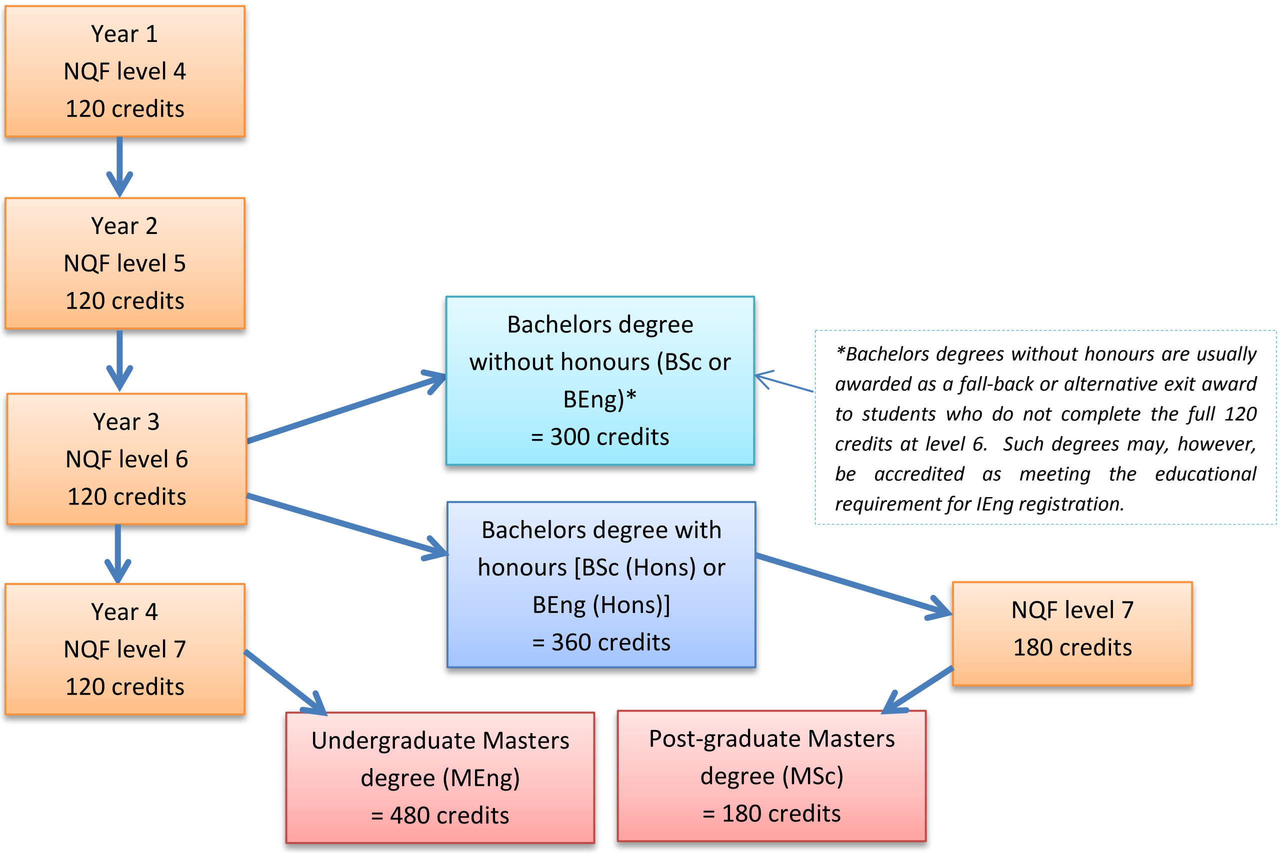

Figure 2 Academic credit structure of UK HE qualifications

2.4.4 Engineering Technician (EngTech)

This represents a grade of engineering registration for those who are expected to be mainly practical in their outlook, working in occupations that sit in between the manual crafts and the engineering professions. Engineering Technicians are primarily trained in the skills related to their specific branch of engineering and will utilise established techniques to carry out technical work, though they may be given some supervisory responsibilities (EC, 2017d). Engineering Technicians are, however, unlikely to be given responsibility for design decisions or innovative problem solving, and therefore tend not to attain senior managerial positions.

Again, there is a linguistic issue here as some commentators query how exactly does a "technician" differ from a "technologist" (and indeed from an "engineer"), and when international agreements are being sought this can be problematic when in some world languages these terms are understood differently from their meaning in English (Augusti, 2009). The Dublin Accord (DA) is the most widely used international agreement for the recognition of engineering technician qualifications and it operates alongside the Washington and Sydney Accords. There is thus, notwithstanding the difficulties of linguistics and interpretation, a system of international recognition for EngTech registrants.

The academic requirement for EngTech registration is quite modest, namely an appropriate level 3 qualification such as a NC or ND, an examination of which is outside the scope of this work, and the PEC requirements stipulated in the UK-SPEC are likewise at a level that would be demonstrable for employees at lower levels of responsibility (see again Table 5 and Appendix 1). Again, EngTech registration is commonly seen by many professionals and by the engineering community at large as a milestone *en route* to IEng or CEng qualification. Consequently, it should follow that since attaining EngTech registration is relatively straightforward for technicians, and the PEIs (who are naturally keen to recruit new members) actively encourage EngTech registration, there should be a good uptake of registrations at this grade. This is, however, not the case, and EngTech registrants are very low in number: in 2016, there were fewer than 16,000 EngTech registrations worldwide, as against 30,000 IEng registrants and 176,000 CEng registrations (EC, 2016).

Since it is desired that a good number of EngTech registrants will progress during their career to IEng and CEng status, the lack of EngTech registrations is of continual concern to the engineering community. In 2013 the IMechE, ICE and IET launched an ambitious scheme to address this deficiency with the support of the UK government. The scheme aims to attract 100,000 new EngTech registrations by 2018, citing that it was estimated in 2013 there were around one million technicians eligible for EngTech registration while just 14,000 were actually registered (The Engineer, 2013). There has been some success in this scheme as the number of registrations has indeed increased to 16,000 in 2016, but it is very difficult to envisage that the target of 100,000 by 2018 will be achieved.

2.4.5 ICT Technician (ICTTech)

This grade is a further entry level grade requiring level 3 educational qualification, aimed at encouraging Information and Communications Technicians to register with the EC. It embraces a group of professions often seen as being on the edge of what constitutes engineering, however, and has to date recruited less than 200 registrants, though to be fair this registration grade was only made available as recently as 2008.

As the name indicates, ICT Technicians are involved with the design, development, implementation, installation, operation, problem solving and security of ICT applications, products, services and infrastructures (EC, 2017e) and enjoy similar modest levels of responsibility and autonomy to EngTech registrants.

Since there are so few registrants, and this thesis is concerned mainly with the BSE professions, this grade of registration is of only passing interest and is not explored further.

The usual routes to registration for the four EC categories are summarised in Figure 3 below.

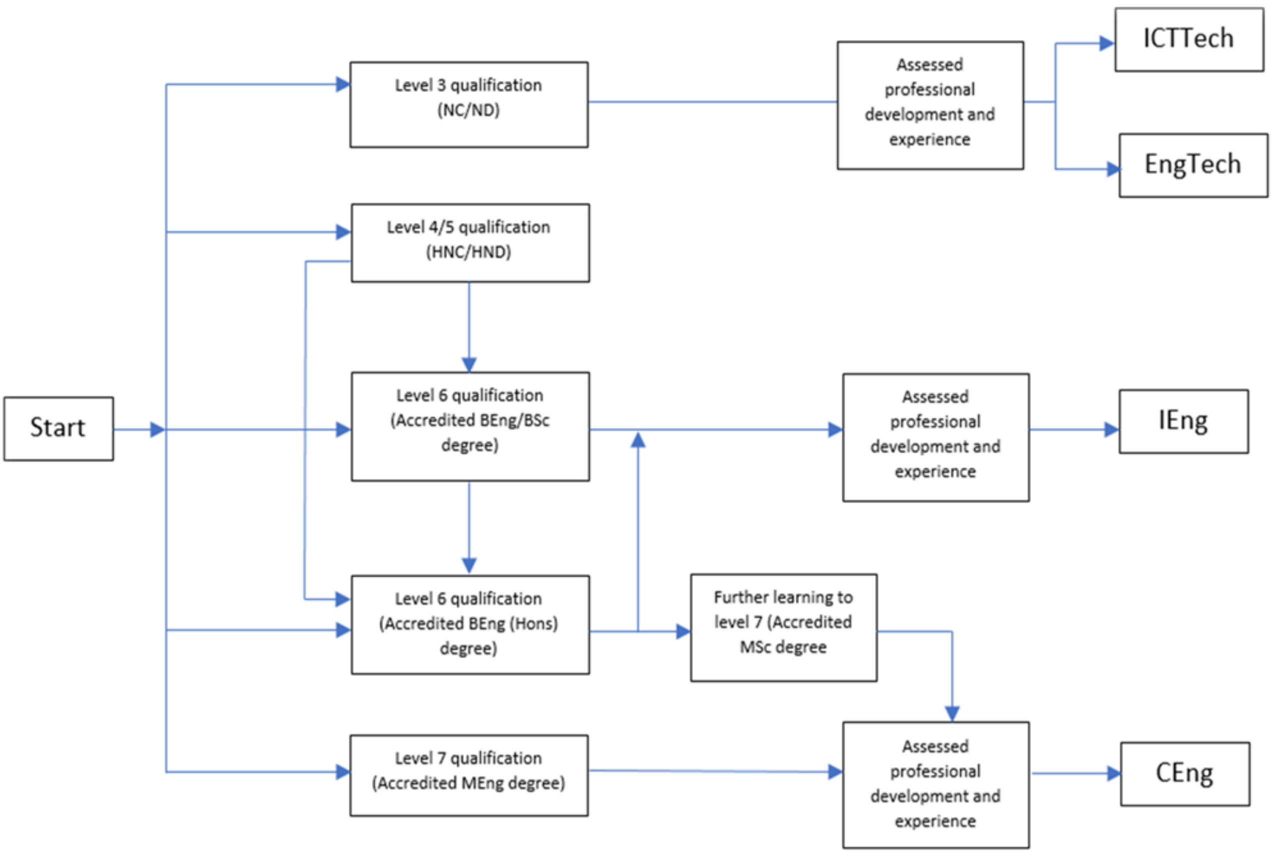

Figure 3 Flow chart showing usual routes to EC registration

2.4.6 PEI membership and member grades

As has already been stated the practice of professional memberships for engineers pervades worldwide, and in some countries, membership of licenced professional societies or institutions is virtually universal. It could certainly be argued that the engineering profession appears much more respected in some countries than in the UK, where only the registration titles described above are protected by law and the title "Engineer" is not. In Germany, for example, appropriately qualified engineers may use the prefix *"Ing"* before their name in the same way as doctors use the prefix "Dr". Unqualified persons calling themselves *"Ingenieur"* in Germany can actually be prosecuted under criminal law and there are several other such examples across the world (Shearman, 2010). This kind of regulation where professional membership is required to maintain legal status to practise certainly strengthens the hand of some engineering societies and institutions across the world. Regulation and licensing is a huge and complex topic worthy of further discussion, and the subject is explored more fully later in Section 2.8.3.

In the UK, Engineers in all fields find it advantageous, normally for career advancement and continuing professional development, to become members of the PEI relevant to their engineering specialism in addition to being on the EC Register. Membership of the PEI is usually seen as synonymous with EC registration, and it is normal to make application for registration at the same time as applying for PEI membership. A 2013 survey commissioned by the EC found that 86% of registered engineers and technicians value their CEng, IEng, EngTech or ICTTech qualification highly, while 43% value it very highly. The corresponding figures for engineers only were 88% and 42% for IEng and 85% and 43% for CEng (Membership Engagement Services, 2013). A similar survey carried out three years earlier asked slightly more detailed questions on this subject and established that members of the ICE and the CIBSE are most likely to value their qualifications very highly (50% and 56% respectively) (ERS Research, 2010).

Notwithstanding the fact that some BSEs specialising in electrical work opt for membership of the IET, energy and facilities management specialists may join the EI, and hospital maintenance engineers and managers are often members of the IHEEM, most BSEs see corporate membership of the CIBSE as the gold standard in their industry. Indeed, across the world, a great many BSEs actively seek CIBSE membership and the institution boasts a presence in 94 countries worldwide and around 3,500 overseas members out of a total worldwide membership of around 21,400 (CIBSE, 2013a).

Various local organisations do, of course, exist overseas and dual or multiple memberships alongside CIBSE membership are not unusual. The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), commonly considered to be a sister organisation to CIBSE, is a very common society for CIBSE members to join, and a Mutual Recognition Agreement (MRA) between the two organisations has existed since 1995 to facilitate engineers to become members of both. Reliable statistics are not kept as to how many engineers are members of both organisations at engineer grades, though the CIBSE-ASHRAE group (a special interest group maintained by CIBSE with around 17,500 members, this being the majority of CIBSE's members) estimates this figure to be around 4,000 worldwide (CIBSE, 2015). Although ASHRAE's membership of about 56,000 across some 132 nations rather eclipses CIBSE's numbers, the two organisations operate under quite different regimes, so to compare membership numbers is not to compare like with like. ASHRAE is a self-regulating "society" rather than an "institution" like CIBSE, and membership is therefore not dependent upon any regulatory requirements or professional registrations, so the popularity of ASHRAE around the world is likely due in large part to its less stringent membership requirements. This is not to say that there are no licencing or regulatory requirements in American states – there most certainly are – but ordinary ASHRAE membership is not conditional upon members being registered or licenced. ASHRAE has always encouraged membership that allows full access to its specialist publications library to all-comers, while the CIBSE, where grades of membership are tied closely to EC registration grades, is much less permissive in this respect.

Table 6 below summarises the various grades of PEI membership together with the educational and professional requirements for membership, alongside the corresponding EC registration grades.

Table 6 Summary of PEI membership and EC registration requirements

[adapted from CIBSE (2017b)]

PEI membership grade	**Corresponding EC registration grade**	**Educational requirement**	**Professional requirement**	**Description**
Affiliate	None	None	Practising in an area affiliated to the branch of engineering	Grade of membership used for persons associated with engineering, though not directly engaged in engineering activities
Student	None	Studying full- or part-time on an appropriate course	None	Introductory grade, used to initially attract entrants to the industry
Graduate	Graduate	Accredited or non-accredited BSc, BEng or MEng degree NQF level 6/7	None	Grade used to maintain engineering registration after completing studies, while gaining sufficient professional experience to qualify for professional membership grades
Licentiate	Engineering Technician (EngTech)	National Certificate NQF level 3	Demonstration of appropriate professional engineering competencies	Member grade for Engineering Technicians working at high level of competence under supervision
Associate	Incorporated Engineer (IEng)	Accredited BSc or BEng degree NQF level 6	Demonstration of appropriate professional engineering competencies	Professional member grade for engineers working at a high level of competence, with a high degree of responsibility
Member	Chartered Engineer (CEng)	Accredited MEng degree or accredited BEng + MSc NQF level 7	Demonstration of appropriate professional engineering competencies	Professional member grade for engineers working at a high level of competence, whilst assuming very high degrees of responsibility
Fellow	No special registration grade	No further educational requirement	Substantial professional experience and demonstration of appropriate advanced level engineering competencies	Professional member grade for senior practitioners

PEI membership at the grades of Fellow, Member and Associate, known as “corporate” grades, entitles engineers to use post-nominal letters in the same way as EC registration does; in the case of CIBSE these post-nominals are FCIBSE, MCIBSE and ACIBSE, and the other PEIs adopt similar conventions. Practising engineers often use two sets of post-nominals, for example CEng MCIBSE, CEng FCIBSE or IEng ACIBSE. As well as these corporate membership categories and their associated EC registration grades, all but two of the PEIs also have a membership grade for EngTech registrants; in the case of the CIBSE this is the Licentiate grade (LCIBSE), though some of the PEIs term this grade of membership Companion. As described earlier, EngTech registrations are nowhere near as numerous as they perhaps should be and this is also the case with Licentiate and Companion memberships. EngTech qualified technicians are specialists in their specific branch of engineering, though EC registration and Licentiate membership requires just a level 3 academic qualification, usually an NC or ND, plus demonstration of a fairly modest set of professional competencies. Many commentators point out that there is a huge gulf between the Licentiate/EngTech grade and Associate/IEng grade, and lament the inconsistency of there being nothing available for intermediate engineers holding level 4 and 5 qualifications.

This is a particular concern in BSE, where for the reasons discussed earlier, many companies employ people holding HNCs or HNDs as engineers. Such professionals, who may be very well versed in engineering competencies by virtue of professional experience, cannot apply for a commensurate professional membership or EC registration grade because such a grade simply does not exist. For this reason, many Engineers with level 4 or 5 qualifications take the stance of either eschewing both EC registration and PEI membership, or conversely, they allow their Licentiate membership and EngTech registration, which they may have attained earlier in their career, to lapse. As previously noted, in 2013 that there were just 14,000 EngTech registrants from a supposed pool of around one million (The Engineer, 2013) and despite a concerted national recruitment drive there are still only 16,000. In BSE, where there are large numbers of engineering technicians qualified with NCs, NDs, HNCs and HNDs who do not qualify for the corporate grades of membership and registration, and are sometimes inclined to see EngTech registration and Licentiate membership as not worth pursuing (Portman, 2014).

The Affiliate grade offered by PEIs is nominally designated for persons associated with an engineering or closely related discipline who are not employed directly as a professional engineer, for instance those with commercial or managerial responsibilities. With reference to the BSE field it is often found that construction professionals like architects, surveyors and construction managers may well maintain Affiliate membership of the CIBSE so that they can enjoy membership benefits, particularly access to its publications library. The non-registered engineers referred to in the previous paragraph may also sometimes take advantage of the Affiliate grade.

A typical progression path for young engineers pursuing IEng or CEng status and corporate PEI membership might be as follows: Full- and part-time students on accredited degree programmes are encouraged to join their relevant PEI at the Student grade. Upon achieving their Bachelor's or Master's degree, they are then invited to transfer to Graduate membership, and upon so doing, the PEI then enters the newly qualified engineer's name on the EC register at Graduate grade. Graduate registration with the EC is limited to a maximum period of 10 years, during which time it is expected that the graduate would be employed in a professional capacity and thus would be gaining the requisite professional experience to apply for IEng or CEng registration along with the associated membership grade. Many engineering companies offer their own structured post graduate training schemes, and these can also be accredited by the PEI, so that their employees may make a smooth transition to corporate membership. Other graduate engineers, not placed on an organised post graduate training regimen, must maintain a record of their professional experience under their own auspices so that they can eventually apply for corporate membership.

The standard route to PEI membership and EC registration then, is that an applicant holding exemplifying academic qualifications supplies evidence in the form of an Engineering Practice Report detailing how they have demonstrated the PECs in professional practice. The final part of the applications process is then a professional review interview arranged by the PEI where an expert panel questions the applicant in detail.

The CIBSE laments that, all too often, young engineers fail to upgrade their Student membership (which is free for full-time students) to the Graduate grade, which requires an annual subscription, and remain lost to the institution and the EC indefinitely. Although this is undoubtedly a valid worry, it is likely that many such engineers return to the fold later in their careers when they need IEng ACIBSE or CEng MCIBSE status for career advancement.

It is worth noting that most of the PEIs offer various routes to encourage and facilitate engineers with non-standard or non-accredited academic qualifications to apply for registration and membership. The CIBSE, for example, invites non-standard applicants to submit details of their qualifications and/or experience for review by its membership panel, who can then advise on the best way forward. Applicants likely to meet the Member or Associate criteria are directed to produce an engineering practice report (in the same way as applicants using the standard route) and, after a competence review interview, can be awarded MCIBSE or ACIBSE without EC Registration. Such engineers are then directed either towards further learning at master's level, or are invited to compile an extended Technical Report that will be judged by the registration panel for the award of CEng or IEng.

This research focuses mainly on the engineering competencies specified for the corporate grades of PEI membership and the corresponding EC registration categories (notwithstanding the importance of the drive for EngTech registrations) since these must be addressed in the content of BSE degree programmes so that such programmes may be accredited by the CIBSE.

2.4.7 Summary of EC registration requirements

In summary, the EC approach to recognising competence of BSEs (and indeed engineers in all disciplines) is as follows:

- The **educational requirement** is usually satisfied by an accredited academic programme: the EC publication, AHEP 3, provides a broad framework with key competencies specified, and this is linked with the QAA benchmark statement for engineering (EC, 2014) (QAA, 2015). The individual PEIs can then interpret this as required for each engineering discipline; in the case of BSE, semi-prescriptive guidance notes are provided by the CIBSE to enable universities to develop courses with confidence, knowing that professional accreditation will be granted (CIBSE, 2012). Further discussion about course design and accreditation follows in Sections 2.6 and 2.7.

- The **professional requirement** is satisfied as described above, by the individual PEIs making judgements as to whether applicants are able to demonstrate professional competence with reference to the PECs listed in the UK-SPEC in a practical setting (EC, 2010). Further discussions on the nature of competence follow in Section 2.5. Professional membership of the various PEIs is normally granted alongside EC registration. Although it is theoretically possible for an individual to be an EC registered engineer without being a member of the appropriate licenced PEI, registered engineers are required by the EC to demonstrate CPD throughout their career, and this can most easily be achieved by the engineer being an active member of the relevant PEI. Thus, registered engineers most usually maintain an appropriate professional membership.

2.5 Defining competence

As has been related, a major part of the requirements for the registration and licencing of engineers is for them to demonstrate professional engineering competencies. The EC defines competence as “the ability to carry out a task to an effective standard. Its achievement requires the right level of knowledge, understanding and skill, as well as a professional attitude.” The EC goes on to propose that this “is part of the requirement (along with commitment) that must be demonstrated in order for an individual to be admitted to the Engineering Council’s register at the relevant level.” (EC, 2014)

Tittagala et al (2016) regard competence as an “underlying characteristic of an individual which enables them to deliver superior performance in a given context”. It is, however, useful to examine more closely what is meant by the terms “competence”, “competency” and the plural form, “competencies”, in the context of engineering. Blandin (2012) suggests that although the words are often used interchangeably and with some ambivalence in everyday parlance, two main semantic categories must be classified with respect to engineering education and training.

The term “competency” and its plural, “competencies” normally describes a person’s ability to perform some specific action, or to achieve expected outcomes in a particular context. These kinds of competencies are directly measurable since the individual’s action or performance can be assessed against an expected outcome. The second category, associated with the term “competence”, is more general and describes the way in which persons may behave, react or conduct themselves in given situations (Blandin, 2012). In pedagogical terms it could be said that individual competencies sit either within either the psychomotor domain (a practical action) or the cognitive domain (an intellectual action), while overall competence is in the affective (behavioural) domain [see Bloom et al (1956)]. This kind of competence is much more difficult to measure.

Following on from these definitions, it could perhaps be considered (though it is undoubtedly an over simplification) that when a person is able to demonstrate a set of individual specific competencies in a certain field or specialism, then that person becomes competent overall in that field. To cite a simple example based on a BSE craft: trainee plumbers will learn to perform the various individual plumbing competencies, such as installing copper tube, installing the components of a bathroom and so on, and it could be considered that once they have mastered the full set of competencies they will, in effect be competent as a plumber. Using this logic it could then be argued therefore that competency is an ingredient of competence, though most would contend that overall behavioural competence is very much more than the sum of its ingredients (Crawford, 2005). The example above does not address the very evident fact that a trainee does not usually behave and perform as a rounded and capable craftsman without acquiring a good deal of job knowledge through work experience, a point that the structure of

National Vocational Qualifications (NVQs) and other competence based qualifications systems around the world recognise and attempt to quantify (King, 2001). From the perspective of an engineering professional, Tittagala et al (2016) suggest that a person usually becomes competent after systematically acquiring and developing a specialist skillset and bank of knowledge, together with the appropriate attitudes and values, through a carefully designed rigorous training regime. Under the EC regime such "training" is considered to include periods of both formal education and experience on the job, and these are monitored and assessed by the PEIs (Tittagala, Hadidimoud, & Liang, 2016).

There are various interpretations about what constitutes knowledge, cognitive reasoning and problem solving abilities, though the EC's interpretations with respect to engineering degree accreditation are perhaps the most useful in the context of this work. In the UK-SPEC (EC, 2010) and AHEP 3 (EC, 2014) the EC provides working definitions for the terms "understanding", "knowledge", "know-how", "skills", "awareness" and "complex" as contributing towards competence, and uses these terms as performance indicators against six "key engineering areas" (these are discussed more fully in Section 2.6). The working definitions given by the EC are as follows:

- **Understanding** is the capacity to use concepts creatively, for example, in problem solving, design, explanations and diagnosis,
- **Knowledge** is information that can be recalled,
- **Know-how** is the ability to apply learned knowledge and skills to perform operations intuitively, efficiently and correctly,
- **Skills** are acquired and learned attributes that can be applied almost automatically,
- **Awareness** is general familiarity, albeit bounded by the needs of the specific discipline,
- **Complex** implies engineering problems, artefacts or systems that involve dealing simultaneously with a sizeable number of factors that interact and require deep understanding, including knowledge at the forefront of the discipline, to analyse or deal with (EC, 2014).

These descriptions fit broadly into the categories defined in Bloom's taxonomy, an educational theory first advanced in the 1950s (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956), though revised by Anderson & Krathwohl in 2000. The qualities, "remember", "understand", "apply", "analyse", "evaluate" and "create" are considered to be skills within the cognitive domain, each leading by increment to the next (Anderson & Krathwohl, 2000).

Blandin (2012) advances a school of thought which recognises the development of specific professional competencies in three different categories, or "dimensions"; these being, as an individual, as a member of the group in which the individual works, and thirdly, as a contributor to the organisation in which that individual works. At the level of the individual, it is suggested, competence has a largely cognitive dimension, in that performing certain actions makes use of cognitive skills such as the application of knowledge, following established rules and procedures, reasoning and problem solving. Individuals will assess themselves as to whether their actions turn out to be proficient, and if so, a feeling of "self-efficacy" will result (Bandura, 1994). In this category, overall competence can be defined against the identifiable competencies. However, when considering the individual as part of the group, competence clearly has an identity dimension: if the individual performs an action according to generally accepted best professional practices in a group, the individual's peers will recognise this. The positive verdict of one's peers is known to engender a feeling of integrating and belonging to the group, while the reverse would also be true (Desjeux, 2004). At the organisational level, any actions performed by the individual can be recognised as contributing positively (or otherwise) to the business of the organisation, and recognition of such can be rewarded by title, position and salary (Blandin, 2007).

These three dimensions are summarised in Table 7 below.

Table 7 The three dimensions of competence and their indicators

[source: (Blandin, 2012)]

Dimension	Focus	Indicators of competence
Cognitive	Individual (micro)	Measurable competencies Feeling of self-efficacy
Identity	Working group (meso)	Feeling of belonging to the group (individual) Judgement of competence (others) Integration into the group
Institutional	Organisation (macro)	Title, Position Level of salary Field of action (prescribed/real)

The competencies specified for EC registration and PEI membership (and indeed those recognised in other accreditation regimes) are by necessity in the cognitive dimension, since these are the qualities which can be readily measured. It is true of course that the PECs require these to be demonstrated by candidates against a contextualised professional setting, but they are inherently and necessarily biased towards qualities that can be self and peer assessed.

As was explained earlier, Blandin's model recognises individual measurable competencies as being largely cognitive and these are characterised by the cognitive resources upon which they rely, these being the application of knowledge, the use of cognitive skills such as reasoning and problem solving, together with the ability to follow rules and procedures. An individual's proficiency in these qualities can be measured within a specific context against standard indicators relating to the context. This is represented in Figure 4 below.

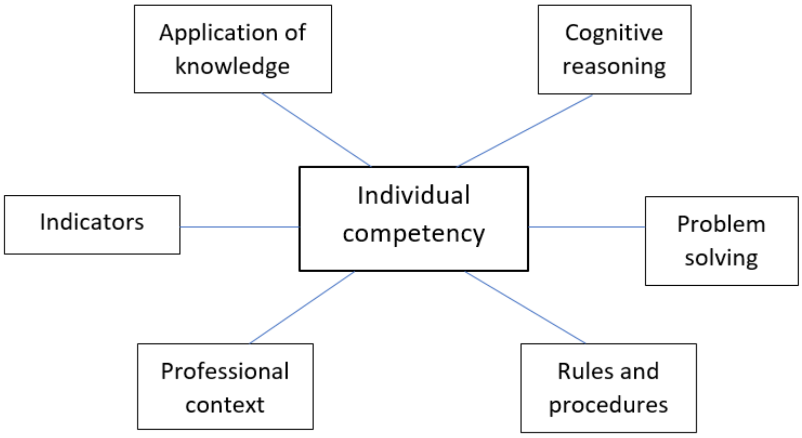

Figure 4 The characteristics of a competency

[adapted from Blandin (2012)]

Although Blandin's terminologies are not an entirely comfortable fit with those used by the EC, when the definitions are considered, parallels can be drawn and consistency can be inferred, though Blandin attempts to quantify the institutional aspect of the individual working within an organisation while the EC does not. When considering the qualities against which the individual competencies are assessed, Blandin (2007) observes five indicators, the central one being "Acting as an Engineer in an organisation", while four other indicators feed into this. This analysis links the cognitive competencies to the notion of overall competence as an engineer discussed earlier. The five descriptions are fairly abstract but can be applied to an "action" in any branch of engineering, and indeed the approach taken by most accreditation systems is to specify generic competencies along these lines.

Acting as an Engineer is the core quality, since to perform any "action" professionally and proficiently requires specific knowledge and skills about the action within the organisational, societal, legal and indeed human, contexts. Eraut (2000) advocates that the skills and qualities associated with acting as a professional engineer include being able to understand and participate in the socialisation rituals particular to the organisation in which the individual works, and being able implicitly to work with institutionally accepted best practices and processes. The term "action" here refers to the type of task an engineer must achieve, and the knowledge, skills and rules and/or procedures that must be mustered and utilised will of course vary according to the task. (A simple example of an action in the BSE field might, for instance, be the design of a heating system for a building.)

The four interdependent qualities identified by Blandin (2007) which contribute to the central competence of "Acting as an Engineer" when applied to any engineering action are identified as the ability to organise human resources appropriate for the action, ability to utilise tools or instruments appropriate to the action, capability to call upon the cognitive resources necessary for the action, and to use the correct reasoning processes for the action. This is summarised in Figure 5 below.

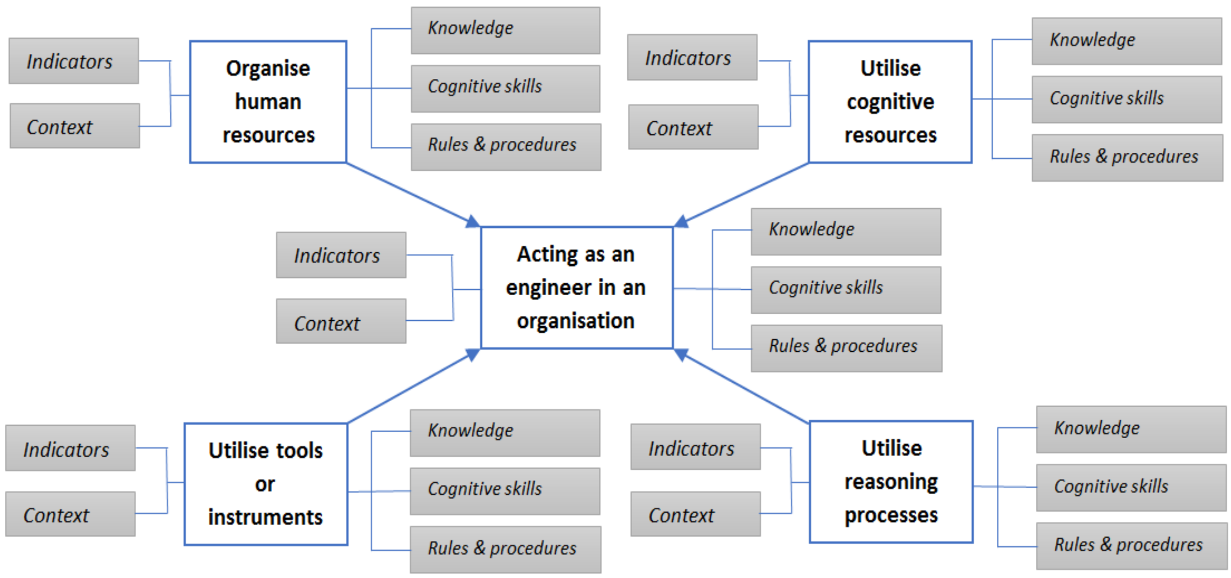

Figure 5 The five engineer competency indicators

[adapted from (Blandin, 2007)]

When interpreting this map, the context relevant to each quality refers to the nature and scope of the activity (whether it is routine, planned or reactionary and so on), the rules and procedures referred to would take account of the range between the internal regulations and practices and the laws and standards regulating the particular engineering specialism, and the indicators are of course the general measurements of proficiency in a company (the quality, reliability and cost of the products, and other similar absolutes).

2.6 Relating engineering competencies to the design of academic courses

Following on from the previous discussion about the nature of competency and competence, it can be considered that a solid foundation of knowledge and understanding of core engineering principles and concepts is an essential ingredient of engineering courses. Once such a foundation is established, then the steady development of critical thinking and analytical abilities to solve engineering problems is crucial to students' future success in professional practice.

There are very real difficulties for academics designing (and delivering) engineering courses, quite apart from the central challenge of constructing an imaginative curriculum that addresses the notion of incremental acquisition of learning referenced above. From a UK perspective particularly, a huge consideration is the widely varying entry qualifications and academic standards among student cohorts. It is well recognised that a significant proportion of engineering students lack the pre-requisite knowledge and skills in fundamental mathematics and physics (Tittagala, Hadidimoud, & Liang, 2016). Such basics are essential to students' progress in engineering studies, and it is very difficult to teach these effectively during the first year of studies when the timescale of BEng and MEng degrees must fit into the normal undergraduate framework of 3 and 4 year degrees. Nevertheless, this is what must be achieved. Tittagala et al (2016) further argue that there is a substantial risk that those students who do enter the programme with the pre-requisite knowledge and skills may tend towards complacency because, put quite simply, they are being taught what they already know – they then miss out on opportunities to acquire further knowledge and deeper affective learning.

This issue is particularly prevalent in the BSE field since, for reasons outlined earlier, so many students arrive with non-standard entry qualifications and varying amounts of professional or technical experience. The Higher Education Academy's (HEA) *Engineering Subject Centre Guide: Guide to Lecturing* recognises and attempts to address this practically, advancing the idea of strategic learning which can lead to acceptable academic achievement for the majority of learners, whilst indirectly promoting facets of deep learning and rewarding better performing students (HEA, 2005).

Basic threshold academic standards for academic courses in the UK originate from the Quality Assurance Agency for HE (QAA), and this body issues "Subject Benchmark Statements" relating to all disciplines and professions. To assist HEIs to develop academic courses in engineering disciplines, the EC published the first edition of AHEP in 2004 and this publication is periodically reviewed, the most recent edition, AHEP 3, issued in 2014 (EC, 2014). The most recent Subject Benchmark Statement for Engineering was issued in 2015 (QAA, 2015) and this embraces the definitions published in AHEP 3, thus there exists a strong consensus about what engineering courses should contain.

2.6.1 Course aims

AHEP 3 adopts an outcomes focused approach in a similar way to the UK-SPEC, and as previously related, this is the focus of the ECs course accreditation regime (accreditation is explored in more depth in Section 2.7).

The AHEP 3 guidance recognises four types of engineering degree programme, which satisfy the educational requirement for EC registration at IEng and CEng levels (EC, 2014):

- Bachelors and Bachelors (Honours) degrees meeting the full requirements for IEng registration, i.e. BSc, BEng, BSc (Hons) and BEng (Hons). (As noted in Figure 2, degrees without honours are usually alternative exit awards for student not completing all 120 credits at level 6, though such degrees can be accredited for IEng registration purposes.)
- Bachelors (Honours) degrees partially meeting the requirement for CEng registration, i.e. BEng (Hons). [BEng (Hons) degrees can be accredited as fully meeting IEng requirements as well as partially meeting CEng requirements when complemented by an accredited MSc.]
- Integrated Masters degrees meeting the full requirement for CEng registration, i.e. MEng.
- Other Masters degrees partially meeting the requirement for CEng registration, i.e. MSc. [Engineers holding MSc degrees can only be deemed to have met the full requirements for CEng registration when their MSc is complemented by an appropriate BEng (Hons) degree]

The general aims for each of these types of degree are shown in Table 8 below – these are quite lengthy and have been paraphrased for the sake of clarity.

Table 8 General aims of four types of engineering degree

[source: EC (2014)]

Type of degree	General aims
Bachelors & Bachelors (Honours) degrees meeting requirement for IEng **BSc, BEng, BSc (Hons) and BEng (Hons)**	• Degrees accredited for the purpose of IEng registration will have an emphasis on development and attainment of the know-how necessary to apply technology to engineering problems and processes, and to maintain and manage current technology, sometimes within a multidisciplinary engineering environment. • The learning outcomes relate to the breadth and depth of underpinning scientific and mathematical knowledge, understanding and skills will be provided to enable the application of engineering principles within existing technology to future engineering problems and processes. Individual and/or group design projects are encouraged. • Programmes will develop a knowledge and understanding of current engineering practice and processes, with less focus on analysis than in programmes accredited for CEng. • Design will be a significant component, especially in integrating a range of knowledge and understanding using current technology.
Bachelors (Honours) degrees partially meeting requirement for CEng **BEng (Hons)**	• Degrees accredited for the purpose of CEng registration develop the ability to apply a thorough understanding of relevant science and mathematics to the analysis and design of technical solutions to improve quality of life. • Graduates must achieve a systematic understanding of the learning outcomes, including acquisition of coherent and detailed knowledge, much of which is at, or informed by, the forefront of defined aspects of the relevant engineering discipline. • Graduate will have the ability to integrate knowledge and understanding of mathematics; science; computer-based methods; design; the economic, legal, social, ethical and environmental context; and engineering practice to solve problems, some of a complex nature, in their chosen engineering discipline. Individual and/or group design projects are encouraged.

Type of degree	General aims
Integrated Masters degrees meeting requirement for CEng **MEng**	• Degrees accredited for CEng registration include the outcomes of accredited Bachelors (Honours) degrees and go beyond to provide a greater range and depth of specialist knowledge, within a research and industrial environment, as well as a broader and more general academic base. Such programmes should provide both a foundation for leadership and a wider appreciation of the economic, legal, social, ethical and environmental context of engineering. • Graduates must achieve a systematic understanding of the learning outcomes described, including acquisition of coherent and detailed knowledge, most of which is at, or informed by, the forefront of defined aspects of the relevant engineering discipline. • Some of the learning outcomes will be to levels deeper and broader than in a Bachelors programme, the balance of which will vary according to the nature and aims of each programme. • Graduates will have the ability to integrate their knowledge and understanding of mathematics; science; computer-based methods; design; the economic, legal, social, ethical and environmental context; and engineering practice to solve a substantial range of engineering problems, some of them complex or novel. Individual and/or group design projects are encouraged and ideally some of these would have industrial involvement or be practice-based.
Other Masters degrees meeting requirement for CEng **MSc**	• Degrees (other than the integrated Masters) accredited as further learning to Masters level for the purposes of registration vary in nature and purpose. Some offer the chance to study in greater depth particular aspects or applications of a broader discipline in which the graduate holds an Honours degree at Bachelors level. Others bring together different engineering disciplines or sub-disciplines in the study of a particular topic, or engineering application, while a further category may be truly multidisciplinary. • Masters programmes also provide an opportunity to integrate the technical and non-technical aspects of engineering and to develop a commitment to professional and social responsibility and ethical codes. • Graduates must achieve a systematic understanding of the learning outcomes, including acquisition of coherent and detailed knowledge, most of which is at, or informed by, the forefront of defined aspects of the relevant engineering discipline. Some of the learning outcomes will be to enhanced and extended levels, the balance of which will vary according to the nature and aims of each programme. • Graduates will have the ability to integrate their prior knowledge and understanding of the discipline and engineering practice with the development of advanced level knowledge and understanding, to solve a substantial range of engineering problems, some of them complex or novel. Individual and/or group design projects are encouraged and ideally some of these would have industrial involvement or be practice-based.

It can be seen that there are different general aims between the degrees which are intended for IEng registration as opposed to those intended for CEng registration, the main variation being that learning outcomes for CEng degrees are expected to address future technologies and new and novel methods of work, while IEng degree focus more on working with established technologies. This is in line with the descriptions of the different grades of registration discussed in Section 2.4, that IEng registrants are expected to be more practical in outlook, while CEng registrants should be at the forefront of development of new engineering knowledge in their field. There is also an expectation in all degree courses that some of the learning arises via individual or group projects, though for CEng accredited degrees these projects ideally have an industrial or practice-based focus.

The general aims are sufficiently similar, however, such that BEng and MEng degrees are not mutually exclusive. Most universities do not therefore provide distinct courses for the two registration categories, indeed this would in most cases be too resource intensive, rather they offer a diet of appropriate modules commencing at NQF level 4 advancing to level 7, and delineate the different aims according to the academic levels. Thus, although there is inevitably a great deal of overlap, levels 4, 5 and 6 generally cover the IEng aims while level 7 picks up the in-depth part of education to CEng level. Free-standing MSc courses have similar aims to those of MEng courses and these courses usually attract graduates who have already achieved the IEng learning outcomes in a previous course of study.

2.6.2 Course learning outcomes

The first and second editions of AHEP provide detailed guidance about general learning outcomes expected for engineering programmes and also list the various skills to be delivered and assessed in five engineering specific “key areas of learning”, providing specific learning outcomes for these. The current third edition of AHEP (AHEP 3) details the same five engineering specific areas of learning, but adds a new “additional general skills” category. This new area of learning represents for the most part the transferable skills that previously were found in the general learning outcomes, and these have now all but disappeared.

Thus the realigned six key areas of learning in AHEP 3 are:

- Science and mathematics;
- Engineering analysis;
- Design;
- Economic, legal, social, ethical and environmental context;
- Engineering practice;
- Additional general skills (EC, 2014).

For each of the degree types listed above, AHEP 3 offers a detailed breakdown of "output standards" alongside the six key areas. In describing the output standards for each key area, AHEP 3 uses the interpretations of competence described in Section 2.5, these being "understanding", "knowledge", "know-how", "skills", "awareness" and "complex". The full learning outcomes are reproduced in Appendix 2.

There is thus quite clear guidance for academics to design (and indeed to review and update) engineering programmes around the requirements of the key documents outlined above. AHEP 3 states that programmes should be designed such that there is sufficient space and opportunity within a logically designed engineering curriculum to effectively address the specified key learning outcomes through systematic and efficient delivery strategies. It further maintains that developing competence in the learners to practice the engineering profession at the defined level, CEng or IEng, should be the foremost responsibility of HE providers, furthermore, learner and institutional expectations should be managed strictly so that the quality of output is not compromised (EC, 2014). This seems all very well, however, as mentioned earlier, to achieve these ideals course designers must attempt to overcome the very real difficulty of the variations in ability and entry qualifications of learners. As previously mentioned, a key challenge that engineering teachers must address constantly is the widely differing levels of what many engineers would call "fundamental knowledge" in mathematics and physics within the same cohort of students. Referring back to the definitions of competence in the previous section, it is argued that students must acquire the abilities to recall and understand this fundamental knowledge before they can utilise the higher level cognitive skills of analysis and problem solving and so demonstrate competence at the levels required for IEng and CEng registration (Tittagala, Hadidimoud, & Liang, 2016).

2.6.3 Design of BSE courses

A further issue when designing BSE courses is the sheer breadth of curriculum that must be covered, quite apart from the necessity of embedding the pure engineering and mathematical content as advocated above. BSE is recognised to encompass a large number of sub-specialisms, including utility services (water supplies, sanitation and drainage), HVAC, refrigeration, electrical installations, electrical power systems, lighting (incorporating use of daylight and artificial lighting), telecommunications and data systems, building services control systems, fire-fighting and fire warning systems (though this is a highly specialised area and there also exist dedicated fire engineering degree courses), lifts and escalators (commonly known as building transportation) and numerous other less well known specialisations. All these areas are of course subject to the omniscient and over-arching ideal of sustainable development in the built environment and working towards energy efficient and zero carbon buildings, and indeed the CIBSE advises that sustainability must be embedded in all learning (CIBSE, 2012).

As discussed earlier there exist three broad sub-disciplines in the industry, namely PHE, MES, and EES, and, as also mentioned earlier, further education colleges can deliver specialist PHE, Mechanical or Electrical versions of BSE HNC and HND part-time programmes to suit local employers' needs. (Though, as also mentioned earlier, PHE courses are very rare and the Mechanical and Electrical Services specialisms are dominant.) The CIBSE's general view about BSE degree courses is, however, that since these courses are aimed primarily at new recruits to the industry who are likely to have scant knowledge about the sub-disciplines, course content should remain as general as possible. The CIBSE therefore suggests that students should receive a grounding in as many of the specialist areas as possible and an in-depth coverage of the most common ones at the early stages of the degree, then students can be afforded the opportunity to specialise according to their interests or talents in the third and fourth years of their course through project and research based work (CIBSE, 2012). The Institution further states that it seeks to encourage new and imaginative interpretations of BSE, and hence does not wish to impose a definitive course structure or curriculum (CIBSE, 2012).

This would appear in itself to be a laudable aim, but the extensive number of sub-specialisms in BSE makes curriculum design a real challenge. To be able to gain a general foundation in at least some of the areas listed above, students must be provided with learning in subjects like human physiology, acoustics and vibration, and building thermal performance, as well as the engineering staples of mathematics, science, heat transfer, thermodynamics, electrical principles and so on. In addition, because BSE is so closely allied to the construction industry, BSE students need significant knowledge about construction technology and design, construction project management and commerce. Since students on pure engineering courses undoubtedly have much more time to concentrate on specific engineering subject matter than those on BSE courses, it could certainly be argued that the notion of in-depth learning and developing the higher level cognitive skills as advocated by Tittagala et al (2016) becomes all but impossible given the range of material to be covered.

In its guidance to institutions seeking to have BSE courses accredited, the CIBSE attempts to strike a balance between recognising the breadth of curriculum and the requirements of the EC. Whilst not being prescriptive, CIBSE offers the following advice (CIBSE, 2012):

- Between 5% and 10% of the course should consist of mathematics, either in its pure form or embedded in other subjects.
- Around 25% of the course should consist of a sound base of appropriate engineering principles, containing the essential elements of materials science, engineering mechanics, physics, fluid mechanics, electrical & electronics principles, and control theory and instrumentation. In addition, it recommends that design methodology, communication skills, experimentation, historical aspects and information technology should be embedded wherever possible.
- Around 40% of the course should consist of the BSE specialist subjects including, heating, ventilation air-conditioning, fan engineering, refrigeration, acoustics and vibration, daylighting and artificial lighting, electrical installation, electrical power systems, building thermal performance, utility services,

building transportation, individual design project work, management, control engineering, health and safety, dynamic modelling and construction law. CIBSE concedes that not all of these topics can be addressed and suggests that as many as possible be embedded as coherent groups of topics within specialist subject areas.

- The remaining 25% of the programme should be devoted to themes relevant to engineering, such as project management, facilities management, legal aspects and so forth.

The CIBSE further advises that the engineering subjects should, where possible, be taught within the context of design, and with regard throughout to the issues of sustainability and health and safety. Multi-disciplinary design is strongly encouraged in project work, such that students have the opportunity to work alongside students pursuing other built environment disciplines, such as architecture (CIBSE, 2012).

Every programme is expected to encompass a major individual investigative project towards the end of the programme (usually in the third or fourth year of study). Such projects should be linked to real problems relevant to the discipline, should be intellectually challenging, and provide scope for initiative, creative thinking and understanding research methods involved.

Further to this, CIBSE wishes to inspire what it loosely terms “professionalism”, and encourages courses to include additional learning that provides insight into a broad range of inter-related social, economic and environmental issues. It argues that an understanding of how the core skills of the BSE discipline and these other areas interrelate and impact upon each other contributes to the development of a rounded professional BSE (CIBSE, 2012).

At accreditation visits the CIBSE anticipates observing strong links between the university department and the local BSE profession, thus underlining the highly vocational nature of BSE courses. It suggests that local practising engineers should become involved by delivering guest lectures or talks, assisting with teaching or assessing design projects, acting as industrial tutors and enabling site visits. CIBSE also recommends that an industrial liaison group is established that meets regularly to advise on programme content, to implement change, and identify local and national needs for graduate employment and how this relates to the programmes. Although CIBSE does not explicitly recommend an industrial placement year be part of BSE degree courses, it does echo the EC’s view in AHEP 3 that providing such an opportunity for students is highly desirable (CIBSE, 2012).

A range of BSE courses offered by UK universities (the full lists shown in Table 2 and Table 3) was examined and the following broad format and common characteristics were observed:

As indicated in Figure 2 each NQF level consists of 120 academic credits at the corresponding level, apart from MSc programmes which consist of 180 credits at level 7. All institutions deliver programmes in a modular format, such that programmes are built from a series of individual modules of study which may be worth 10, 20, 30, 40 or (exceptionally) 60 credits.

Level 4, year 1 – At this stage students are provided with opportunities to build up a knowledge base of key engineering- and construction-based principles and concepts upon which learning in subsequent years will be developed. There is a strong focus on reinforcing fundamental engineering knowledge and mathematics, and developing analytical approaches to problem solving.

Level 5, year 2 – In the second year the tendency is to link fundamental knowledge and principles to more subject specific learning. Most BSE courses allow the teaching (and often assessment) to relate to vocationally relevant design projects based on real buildings. Analytical abilities are further reinforced and advanced to encourage critical thinking when solving complex problems. The use of specialist industry standard software is most often introduced at this stage, though some courses provide a taster in the first year.

Industry placement year – Although not mandatory, the sandwich year features in all BSE courses. The provision of such an opportunity is well-recognised as enhancing employability prospects for graduates, as well as providing a solid vocational context for prior and future learning (CIBSE, 2012). Complementary workplace learning is further explored in Section 2.6.4.

Level 6, year 3 – At the higher levels there is more emphasis on providing an intellectual challenge, alongside constant reinforcement of engineering fundamentals in appropriate vocational contexts. Use of industry standard analytical software tools to solve engineering problems and contribute to design work is advocated. All BSE courses have individual research projects of some description at level 6, usually in the form of a dissertation, though design projects with a research aspect are also seen. Students may graduate at this level with a BEng (Hons) degree.

Level 7, year 4 – There are effectively two types of level 7 provision: a complementary additional undergraduate year for students aiming towards the MEng qualification, as opposed to a free-standing post-graduate MSc course, which may be one year full-time in duration, or two years part-time for employed students (in some universities there are also distance or blended learning options available – see Table 3). Across the different universities offering these qualifications there is much more variation seen between subjects taught than at the other undergraduate levels.

- In MEng programmes all courses seem to offer a mixture of higher level engineering subjects such as Control Engineering, Smart Technologies and Energy Management, and the more commercial associated subjects such as Leadership and Management, and Project, Personnel and Facilities

Management are seen. There is also a certain consistency of approach in that interdisciplinary collaborative projects comprise large parts of the learning at this level.

- Two main types of BSE MSc programmes are seen, and these are loosely defined by academics as “conversion courses” and “specialist courses”.

    - As a general observation, conversion MSc courses tend to be somewhat “lower tech” than MEng level 7 years since, to make courses viable, universities must attract students from a wide range of backgrounds, and often applications are received from students with non-engineering entry qualifications. It is therefore not always possible to include the higher level engineering materials where the entry knowledge base is highly advanced or specialist. Many conversion MSc programmes teach the basic tenets of BSE systems and design, subject matter which would normally be taught at lower levels on undergraduate MEng courses. In conversion MSc’s there is much more emphasis on the softer engineering skills such as Management, Commerce and so on[4].

    - Specialist MSc courses are designed more for BSE and other engineering graduates and therefore tend to build upon prior engineering knowledge and skills. These programmes often mimic (and even borrow modules from) MEng courses, and the higher academic credit tariff (180 as opposed to 120 at level 7 of an MEng course) is normally fulfilled by extra project work of a research and/or practical nature.

As previously mentioned, a large number of BSE students are part-time, employed in the industry, and often enter degree courses either at level 5 with an HNC entry qualification, or at level 6 with an HND or FD. Effectively such students already have the advantage of an industry placement and there is also considerable academic benefit to integrating them with students who have taken the full-time study route. As previously recounted in Section 2.4.3, the part-time attendance mode is facilitated by delivery of learning over a longer time frame.

A typical, generalised course structure is shown in Figure 6 below.

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[4] *Such courses can, however, be accredited by the CIBSE as partially satisfying the academic requirement for CEng registration where there is sufficient content at an appropriate level and the requirements of AHEP 3 are met. Graduates from such courses applying for EC registration and CIBSE membership will, however, also have their prior qualifications considered as part of the application process.*

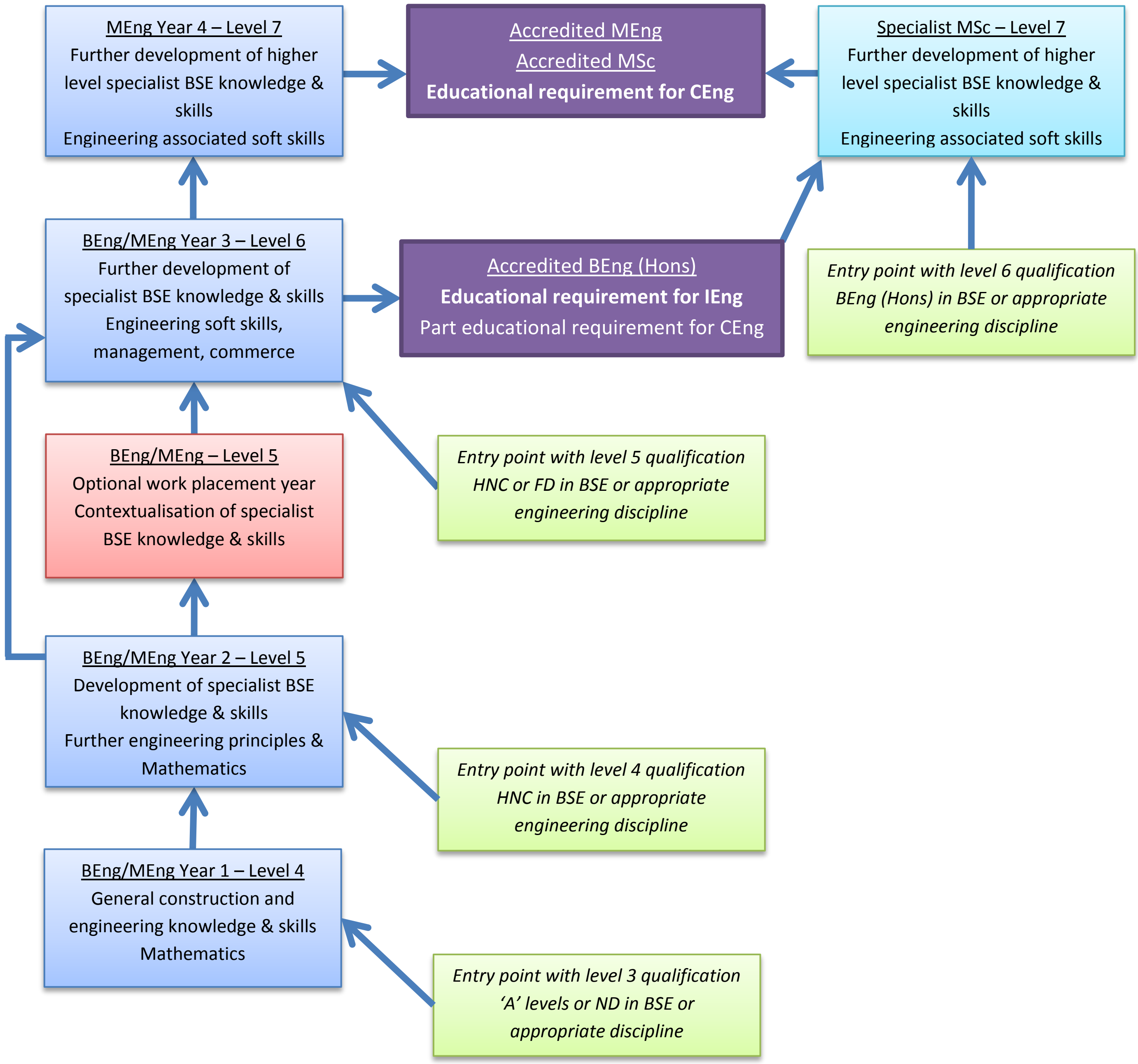

Figure 6 Typical structure of UK BSE programmes

2.6.4 Immediate international comparisons of BSE academic programmes

A number of BSE and similar programmes in Hong Kong, Ireland, Germany, Australia and USA were examined alongside UK programmes highlighted above, and various literature was reviewed in this connection. Whilst localised diversity with respect to course content was expected – and found – an almost surprising amount of similarity across curricula and course structures was also discovered. In terms of syllabus, notwithstanding relatively minor local differences, very similar curricula were observed, with the fundamentals of engineering, mathematics, construction technology and common BSE specialisms all well represented. Structurally, courses were also found to be strikingly similar, with the commonly observed two educational cycles in evidence: an undergraduate cycle which culminates in the award of a bachelor's degree, and a post-graduate cycle linked to master's degrees.

Several practices highlighted above in Section 2.6.3 concerning the design of BSE degrees in UK are in evidence across the world:

The project based approach to learning described in the previous section [and recommended by the CIBSE (2012)] also appears in several BSE and AE programmes throughout the world, often these programmes being based upon an American approach described by Alahmad, Hess, & Johnson (2007), though this is very similar to the approach proposed by the CIBSE. Essentially this methodology is concerned with students "learning through doing" and encourages vocationally relevant project based materials to be used as much as possible for teaching and assessment purposes. A multi-disciplinary approach to projects is further recommended, where students are encouraged to collaborate with others who may be studying different, though related, disciplines (Alahmad, Hess, & Johnson, 2007).

The importance of providing a fundamental underpinning basic education consisting of mathematics, science and engineering principles alongside essential construction technology in Architectural Engineering (AE) courses is reviewed in some detail by Megri (2011) (AE being the preferred term for BSE in USA). This review describes how such an approach is growing in acceptance across USA, and in courses overseas influenced by the American Accreditation Board for Engineering and Technology (ABET) (Megri, 2011). Similar arguments are advanced by Cai (2010) in the context of a shortage of HVAC engineers in the rapidly evolving economy in China. Again, the approaches outlined are broadly analogous to the CIBSE's advice on course development (CIBSE, 2012) and demonstrate a high degree of commonality of purpose amongst course providers irrespective of national boundaries.

The practice of complementary work based learning also appears in several world locations, and though it goes under various guises, the practice of sandwich placements completed by students whilst engaged in formal education, similar to the UK approach is a popular practice in BSE and various engineering disciplines. Sandwich courses were defined by the UK Department of Education and Science (DES) some years ago as courses which incorporate periods of organised full-time work experience alongside full-time study, the work experience placements being linked in some measure to the course content (Brewer, 1990) and this definition is still very current.

Au Yeung et al (1993) describe, in the context of developing BSE degree programmes in Hong Kong, how from the 1970s a connection between education and work experience was inferred, and became more prominent. This approach is commonly termed "co-operative education" and courses in numerous engineering disciplines have been developed in several parts of the word which involve teaching students through formal instruction in educational establishments alongside complementary placements in appropriate work settings. Naturally, such an approach requires extensive co-operation between supporting employers and academic institutions, which presents various challenges (Au Yeung, et al., 1993).

The nature and extent of education tied to work based learning varies throughout the world and different practices are adopted. Typically, four types of work experience programmes are identifiable (Turner, 1981):

- A work based assessment may be an academic requirement for the award of the degree;
- Demonstration of professional competence may be a professional licensing requirement;
- Demonstration of practical skills may be an admission requirement for an academic course;
- Graduates may be required to work for the state as repayment for a free education.

These four categories may be delivered using techniques such as internships, professional practice programmes, experiential education or sandwich programmes. In most engineering disciplines, and indeed in BSE, sandwich programmes are the most common example of practical work experience as a degree requirement, though as described previously, sandwich placements are usually not compulsory and sandwich and non-sandwich versions of degree qualifications can be awarded.

2.7 Accreditation of academic courses

Accreditation of degree programmes by recognised professional and statutory bodies is a well-respected quality assurance tool, ensuring that programmes meet the standards set by the relevant professions. Professional body accreditation of engineering degree courses in the UK commenced in the early 1960s and has undergone several changes in approach, culminating in the adoption of the methods set out in today's UK-SPEC (EC, 2010).

As previously detailed, the EC sets and maintains standards for the engineering professions and publishes these in the UK-SPEC, which sets out lists of PECs as checklists of competencies that should be demonstrable by practising engineers seeking EC registration. Bearing in mind previous discussions about the nature of competence as an engineer, it is self-evident that these competencies cannot be fully taught and assessed in universities, rather they must be acquired in professional practice extra to the formal education process. The learning delivered by a university course serves, in effect, as preparatory knowledge on the way to acquisition of the full requirements of the UK-SPEC. Therefore, alongside any specialist guidance provided by the relevant PEI, the EC's AHEP 3 publication is designed to assist universities to develop academic courses to deliver such learning and ensure that they are suitable for accreditation (as described in Section 2.6) (EC, 2014).

The EC (2014) further considers that, as well as a quality assurance tool, accreditation can also be a useful developmental process, since it provides educational institutions with a structured ongoing mechanism to assess and evaluate their programmes. An important development in 2006 was the adoption by the QAA of the EC's standards for accredited engineering degrees (that is AHEP 3) as the subject benchmark statement for engineering (QAA, 2015). This alignment removed much of the duplication of effort required to satisfy the requirements of the QAA subject benchmark alongside those of professional accreditation, and was therefore strongly supported by the engineering academic community (EC, 2014). It is generally accepted that this approach enables HE providers to work from a single point of reference to meet academic and professional standards, and thereby minimise the risk of contradictory interpretations of accreditation requirements (Tittagala, Hadidimoud, & Liang, 2016).

As previously stated, Engineers (and Engineering Technicians) applying to join their PEI at one of the corporate grades alongside EC registration, would usually make a single membership application to cover both processes, which should satisfy both the academic and professional requirements already described. PEI accreditation of an engineering course means that graduates from that course will be automatically adjudged to have satisfied the educational requirement for the professional membership grades and associated EC registration status, and thus the academic requirement is very easily and neatly satisfied.

For the PEIs then, accreditation of academic study programmes effectively streamlines the process of assessing membership and registration applications, since it means that their membership panels do not need to make any judgement about the validity or relevance of applicants' academic qualifications. In general, universities must be sure to design their engineering courses such that PEI accreditation is possible, and they normally ensure that their courses remain accredited as part of day to day course management processes. Without professional accreditation, universities can be greatly disadvantaged in their efforts to attract well qualified students. The advantages for students are that, besides being assured of fulfilling the academic requirements for EC registration, they will be pursuing an academic programme which has been professionally scrutinised and is likely to provide the best prospects for future employment and advancement in their chosen profession (Levy, 2000).

2.7.1 Accreditation process

The EC (2014) maintains that the accreditation process is essentially one of peer review and is applied to individual programmes, not to a university or to a department. The PEIs are licenced to grant accredited status to courses of study following a rigorous inspection and vetting process, and this is normally carried out on a five-yearly cycle. To maintain a consistency of approach, some PEI's in the UK have entered into agreements where they can join forces in accreditation, and this also assists the smaller PEIs who may not have the resources available to carry out accreditations independently. For instance, the ICE, which is the third largest PEI, and three much smaller institutions, the IStructE, CIHT, and IHE, are represented by a joint organisation known as the Joint Board of Moderators (JBM), and it is claimed that this organisation represents some 100,000 engineers across the world.

Each PEI (or Joint Board) publishes details of its own processes for accreditation, though they are all fairly similar. Typically, the PEI requires the educational institution to make a documentary submission, which will include information about the structure and learning outcomes of the programme, the teaching, learning and assessment strategies employed, the human, physical and material resources available to the course, and the professional registration and qualifications of staff. In addition the institution will supply information about its quality assurance policies and procedures, its academic regulations regarding progression and the award of degrees, and so on.

The PEI then appoints an accreditation panel consisting of academic and industrial members who have been trained in the principles of accreditation and are knowledgeable about its requirements. The panel visits the institution to carry out a thorough examination of the management, content and general quality of the course, alongside the standards achieved by students. The panel would expect to meet staff and students, and some PEIs (CIBSE notably) expect their panels to be able to meet representatives of the industrial liaison group. During the visit, panel members will anticipate being able to inspect all teaching facilities, including laboratories and to review examples of student work and examination scripts, along with marking schemes, external examiner reports and general quality assurance documentation.

2.7.2 Accreditation philosophy

The landmark *Hamilton Report* of 2000, which compared the operation of the engineering profession in the UK with other countries, argued that the UK had a "comprehensive, but rather convoluted approach" to accreditation (Hamilton, 2000). This pronouncement was just a few years before the most recent realignment of the EC and revision of the responsibilities of the PEIs, and also before the QAA had adopted the EC's definitions as the subject benchmark for the profession. Hamilton (2000) further suggested that due to the amount of responsibility devolved to the PEIs, and universities seeking to satisfy the diverse requirements of both the EC and the QAA, that the course accreditation process could well be considered to be unnecessarily complex, burdensome for universities and possibly even subject to inconsistencies.

The subsequent realignment of the EC and the publication of the UK-SPEC seems to have somewhat resolved Hamilton's concerns on this front, as well as addressing further issues that are described later in this section. The EC's accreditation philosophy is now recognised as being primarily "output driven"; that is to say, the quality of student academic performance (the output) is considered of paramount importance, whilst no particular judgement is made about the academic quality of entrants to the course (the input). As noted above, the accreditation process does of course also look at other factors relating to quality, such as management and administration of courses, levels of staffing, resources, facilities offered by the institution, standards of teaching, learning and assessment, industrial links and so on, and, whilst AHEP 3 offers guidance, the PEIs to an extent can apply their own standards here.

The output driven philosophy is a relatively new position and only came into force with the first edition of the UK-SPEC in 2003. Under SARTOR 3 in 1997, in a move to boost the professional standing of engineering courses, along with safeguarding mutual international recognition of engineering qualifications, an entry qualifications quota system was set for accredited degree courses (ECUK, 1997). This stipulated that 80% of entrants to a CEng accredited MEng degree must have a minimum of 24 'A' level points (this equated to three 'A' levels at grade B under the 'A' level points system in force at that time) and for a BEng course 80% of entrants should have 18 points (three 'A' levels at grade C) (Hamilton, 2000). At that time, before the establishment of the national qualifications framework (NQF) it was not easy to equate vocational qualifications like NCs and NDs with traditional academic qualifications like 'A' levels, so this made it more difficult for universities to allow applicants holding non-standard entry qualifications access to accredited engineering programmes. In answer to the criticism that this approach could be considered too demanding, Hamilton (2000) contended that this system recognised the need for an "elite route" to MEng and CEng, and further that the system could offer an autonomous route to IEng, which need not simply be a degraded MEng. This move came at the same time as SARTOR 3 raised the academic requirement for CEng registration from a Bachelor's to a Master's degree, so it caused some consternation in the engineering community.

The EC's Chief Executive Officer between 2002 – 2010 and, prior to this, Chief Executive of the CIBSE, Andrew Ramsay, records that this stance became unpopular among the larger and more influential PEIs including the IMechE, ICE and IET (Ramsay, 2012), and the CIBSE also argued vehemently that such a stipulation dissuaded large numbers of bright and able young people from non-academic backgrounds from entering engineering education. Many senior figures in CIBSE contended further that such entry quotas discriminated against large numbers of BSEs who enter the profession through non-standard routes (CIBSE, 2011); many start their careers in trades like plumbing or electrical installation for instance, and progress through from craft training to technical education and ultimately to university studies, and thus would never be likely to hold a qualification equating to three 'A' levels. The stipulations of SARTOR 3, it was argued, actively discriminated against such people who often are the core professionals in BSE. The introduction of the UK-SPEC in 2004 changed this focus radically to the output based system described above.

The EC's accreditation philosophy sets out to be as general as possible not only to satisfy the various branches of the profession, but also to fit in as much as possible with other accreditation systems around the world.

2.8 Accreditation of engineering courses worldwide

This account has focussed thus far on accreditation in the UK, but of course, professional accreditation of engineering programmes is utilised throughout the world for similar reasons. Unsurprisingly, there are differences in approach but the primary imperative of accreditation is the same: to maintain the quality and status of engineering graduates, and hence the competence of engineers. Outside of the Western industrialised nations there is a distinct possibility, particularly in some third world countries, that higher education institutions (HEIs) are subject to less state regulation, so there is thus an argument that accreditation also fulfils a public accountability role. Codner & Patil (2007) argue that quite apart from the issue of maintaining standards for the engineering professions, accreditation represents an assertion of civic responsibility and a guarantee of the quality and academic reputation of academic institutions.

Codner & Patil (2007) further describe how the steady onset of globalisation in the new millennium is affecting the engineering professions and engineering education. The constant growth in global industrialisation fuels an ever-increasing need for more and more qualified engineers. Naturally, this results in more engineering courses becoming available, and in addition, enhances the need for international mutual recognition of engineering qualifications as engineers move to parts of the world where they are needed. As well as there being huge numbers of engineering courses becoming available in parts of the word where there may well be less regulation of educational establishments, alternative teaching and learning methods such as distance and e-learning have emerged, where it is hard to judge the quality of courses.

There would therefore appear to be, now more than ever, a need for a model of engineering accreditation that facilitates international quality assurance and might be used to assess the professional competencies of engineering graduates on an internationally recognisable basis (Codner & Patil, 2007). This is not an isolated, or necessarily new, view: Dodridge (2002), Szanto (2005), and indeed others, argue that an international approach to accreditation of engineering courses could well be used as a tool to enhance the progress of international mutual recognition of both educational qualifications and professional experience. Good accreditation practice, it is argued, can enhance mutual recognition of qualifications, and this works hand-in-hand with maintaining professional standards.

Notwithstanding the above arguments, there are surprising similarities in the accreditation approaches around the world, and just three main systems of accreditation of engineering courses are found. Specifically, these are the USA system, the Asia-Pacific system and the European system; and significantly the WSDA approach to mutual recognition of qualifications and certification attempts to straddle all three.

In the USA, the Accreditation Board for Engineering and Technology (ABET) evaluates engineering educational programmes at institutions and focuses in particular upon judging the quality of the programme based upon outcomes rather than a judgement of the particular institution or department, an approach which very much echoes the UK system and the WSDA approach. Unsurprisingly, there are several other parallels between these. This is quite different to the Asia-Pacific approach, which attempts to cover a region that has seen, and continues to see, rapid economic and industrial expansion. Such expansion has led to an enormous growth in engineering education, and this is growing faster than anywhere else in the world. In such circumstances Cordner & Patil (2007) observe that the academic quality of educational institutions can be compromised and hence the local accreditation system pays much more attention to inspecting the quality of the institution than do the American and European systems.

The modern European system traces its roots back to the Sorbonne Declaration of 1998, which gave rise to the Bologna Process (BP) the following year, and this continuing process aims to set up a system of transparency of HE qualifications throughout Europe and across the world. Under the BP, to aid transparency and mutual recognition of academic qualifications, all European countries (and those outside Europe wishing to enjoy the benefits of mutual recognition of qualifications) must adopt what is termed a "binary system" of HE. The binary system requires member countries to implement a system based on two educational cycles, undergraduate and post-graduate, though many countries already had this prior to the launch of the BP. Several national accreditation systems were able to function well under the BP system without the necessity of making too many revisions, particularly the UK's EC and the German Accreditation Council (*Deutscher Verband Technisch-Wissenschaftlicher Vereine [DVT]*). Other countries have had to make more significant adjustments to their policies and procedures to work towards the goals of transparency and (ultimately) harmonisation (Augusti, 2009).

From a UK perspective, the EC's international mission is to ensure that UK engineering standards are globally recognised and thus facilitate international mobility of engineering professionals. The EC therefore endeavours to actively boost overseas recognition of the CEng, IEng and EngTech qualifications, always seeking agreements and accords with foreign professional bodies and government agencies to align professional engineering qualifications and practices (EC, 2013). In pursuit of this aim, the EC is the partner representing the UK in the European Federation of National Engineering Associations (FEANI), and is also a member of the European Network for the Accreditation of Engineering Education (ENAEE) and the International Engineering Alliance (IEA). The EC is also the UK signatory to the WSDA international agreements, as well as being the holder of the UK Section of the International Registers of Professional Engineers (IntPE) and Engineering Technologists (IntET).

The FEANI, first established in 1951, has always pursued an ideal of establishing a framework of international mutual recognition of qualifications. It now represents 34 European member countries and is the body charged with taking a leading role in the BP. The FEANI enthusiastically promotes use of the

European Engineer (EurIng) qualification and title, this being essentially an equivalent qualification to CEng, and claims that this facilitates the mobility of engineers both inside and outside Europe (FEANI, 2013). As the UK's representative of FEANI, the EC has responsibility for receiving applications for EurIng registration. UK registered Chartered Engineers are entitled to register through the FEANI as a European Engineer and use the pre-nominal of EurIng, though there is no European Engineering Technologist title equivalent to the IEng qualification.

As mentioned above, the EC is also the UK's representative in the ENAEE, a European accreditation framework for engineering courses which advocates and promotes the EUR-ACE joint accreditation system (Augusti, 2009). This system, originating under the auspices of the BP, means that courses accredited by professional bodies in member countries are recognised by the equivalent professional bodies in other member countries.

Outside of the European system, the International Engineering Association (IEA) represents six international mutual recognition agreements. Three of these agreements are the WSDAs, which, as the following commentary describes, define both educational requirements and professional competencies for engineers. The other three agreements are the Asia Pacific Economic Cooperation Engineer Agreement (APECEA), The International Professional Engineer Agreement (IPEA) and the International Engineering Technologist Agreement (IETA), and these cover recognition of professional competence standards but not educational requirements (IEA, 2010).

2.8.1 The Washington, Sydney and Dublin Accords

The Washington, Sydney and Dublin Accords (WSDAs) represent a collection of three international agreements which facilitate mutual recognition of engineering qualifications between member countries, and they may be considered collectively to be an accreditation model that seeks to build bridges between the three different accreditation systems described above (IEA, 2013a). Those countries working within the European and American systems tend to work well under the WSDA approach, though countries in the Asia-Pacific region must in many cases make considerable policy adaptations to facilitate membership of the Accords (Kasuba & Ziliukas, 2004).

The WSDA model was initiated in 1989 by six predominantly English-speaking countries (Australia, Canada, Ireland, New Zealand, UK and USA) with the signing of the first of the three agreements, the Washington Accord (WA) in 1989. The WA is recognised universally as a multi-lateral agreement between bodies responsible for accreditation or recognition of tertiary-level engineering qualifications within their jurisdictions, who have chosen to work collectively to assist the mobility of professional engineers (IEA, 2017a). The term "tertiary-level" here refers essentially to the equivalent of CEng level qualifications in the

UK, and the WA also guarantees that graduates of engineering programmes accredited by any of the signatory bodies are recognised within their own jurisdictions.

The signatories to the Accord, these being the regulatory bodies for engineering in each of the member countries (EC equivalent bodies), maintain that they are committed to developing and recognising good practice in engineering education, and they agree to participate in activities addressing the growing necessity for mutual recognition of engineering qualifications across borders (IEA, 2017a). Kasuba & Ziliukas (2004) record that since the WA was primarily initiated by countries with a reasonably close match of existing academic programmes and accreditation processes, and these countries did not need to introduce any significant reforms, some considered the WA in its early years as being a closed consortium of English-speaking countries. Since its 1989 inception, however, the WA's original six members have welcomed a further 12 nations as full members (China, Taipei, Hong Kong, India, Japan, Korea, Malaysia, Russia, Singapore, South Africa, Sri Lanka and Turkey), and six more with provisional membership status (Bangladesh, Costa Rica, Mexico, Pakistan, Peru and the Philippines) (IEA, 2017a). Provisional members are recognised as having appropriate systems in place and are working towards full membership.

The Accord further acknowledges that accreditation of engineering academic programmes is a key foundation for the practice of engineering at the professional level in each of the member states, and underlines the importance of mutual recognition of accredited engineering degree programmes. It also establishes and benchmarks the standard for professional engineering education across those bodies and thus takes a leading role in both standardising accreditation practices, and recognising common features where accreditation practices in member countries differ (Kasuba & Ziliukas, 2004).

Several years later, in 2001, the Sydney Accord (SA) agreement followed, and this constitutes a similar understanding for qualifications for Engineering Technologists and Incorporated Engineers, embracing qualifications that can be considered as equivalent to IEng qualifications in the UK, whilst fully recognising the importance of such professionals as part of a wider engineering team. Throughout its documentation the SA uses the term "Engineering Technologist" for this type of engineering professional, though it remains mindful that other countries use different terms, such as "Science Technologist", "Associate Engineer" and "Incorporated Engineer" (IEA, 2017b).

This Accord was signed by seven founder members, Australia, Canada, Hong Kong, Ireland, New Zealand, UK and South Africa, and has welcomed three further members since inception, USA, Taipei and Korea; also Peru currently holds provisional membership status (IEA, 2017b).

The last of the three agreements, the Dublin Accord (DA), was then signed in 2002 in the first instance by the UK, Ireland, South Africa and Canada with the aim of mutually recognising the qualifications for Engineering Technicians (UK EngTech equivalents) in the four countries. Australia, New Zealand, Korea and the USA have since joined the Accord (IEA, 2017c). In the DA documentation, the term "Engineering Technician" is preferred, though the Accord recognises that equivalent professionals are sometimes termed "Certified Technician", "Professional Technician" or "Engineering Associate" across the different member countries (IEA, 2017c).

The philosophy of the WSDA approach is described by the IEA as being output driven in a similar way to the EC's approach, recognising the three roles of Engineer, Engineering Technologist (Incorporated Engineer) and Engineering Technician, broadly equivalent to the EC's definitions. There is naturally a degree of overlap between roles, but the distinctive competencies are recognised and defined in detail (IEA, 2013b).

The WSDA approach recognises development of engineering professionals in any of the three categories as an ongoing process with defined stages (IEA, 2013b):

- The graduate stage, which involves working towards an accredited educational qualification. This process should involve the building of a knowledge base such that graduates will be able to continue formative development independently once they are in professional practice.
- The professional registration stage involves the graduate gaining experience and knowledge in professional practice, until they can demonstrate competence at the level required for registration.
- Once registered, engineering professionals are expected to undertake regular continuing professional development such that they maintain and expand their competence throughout their working lives.

Again, this system resonates with EC methodology of an educational requirement, a professional requirement and a requirement for ongoing CPD in professional practice. To recognise the first and second stages of development the WSDA defines "graduate attributes" and "professional competencies" and the parallels with the EC approach of setting out accredited course requirements in the AHEP 3 publication followed by demonstration of the PECs defined in the UK-SPEC is striking.

The graduate attributes are essentially a series of statements of competence outlining the attributes expected of graduates from accredited courses (which can be refined by range statements appropriate to the nature of each programme) to allow comparability between educational programmes. The graduate attributes further enable member countries to develop outcomes-based accreditation criteria, as well as assisting non-member countries seeking signatory status to develop the same. The principle is that graduates from different, though comparable, programmes could enter employment and be equipped to undertake training and experiential learning leading to professional competence and engineer registration (IEA, 2013b).

The graduate attributes are structured using twelve headings, namely: Engineering Knowledge, Problem Analysis, Design/ development of solutions, Investigation, Modern Tool Usage, The Engineer and Society, Environment and Sustainability, Ethics, Individual and Team work, Communication, Project Management and Finance, Lifelong learning. Each heading is designed to identify the differentiating characteristic that allows the distinctive roles of engineers, technologists and technicians to be distinguished by range information. The tabulated list alongside the defining range statements in respect of WA, SA and DA competencies is reproduced in Appendix 3.

The second stage of development involves the acquisition of professional competencies. The WSDA approach is again similar to the EC methodology in that it recognises and defines a series of attributes necessary to perform a range of activities to the expected satisfactory standards in professional practice. The professional competence attributes as defined correspond largely to the graduate attributes, but with a more holistic emphasis (IEA, 2013b). As previously argued in the discussions on the nature of competence in Section 2.5, professional competence is much more than a set of individual competencies, and performance as an engineer must be assessed holistically (Blandin, 2012).

In a similar way as for the graduate attributes, the professional competency profiles are written as a series of statements relating to each of the three categories of engineering practitioner already defined. In this case there are thirteen elements: Comprehend and apply universal knowledge, Comprehend and apply local knowledge, Problem analysis, Design and development of solutions, Evaluation, Protection of society, Legal and regulatory, Ethics, Manage engineering activities, Communication, Lifelong learning, Judgement, and Responsibility for decisions. These are also shown in a table alongside the defining range statements for the three types of engineering professional in Appendix 3. It is self-evident that these titles lend a more holistic and rounded approach to the assessment of competence in each case.

Both the professional competency and graduate attributes tables must be read alongside three further tables which show contextual definitions to be applied, common expectations of knowledge, and generic ranges of engineering activities (IEA, 2013b) and these are also reproduced in full in Appendix 3. The approach seems slightly convoluted and takes some effort to interpret, but once understood is very utilitarian.

The WSDA system undoubtedly complements the EC's outcome based philosophy for judging the competence of engineers, using a similar system comprising of a list of engineering competencies, and this is of course why the EC approach fits so comfortably. The same question that was applied to the EC approach in the UK must therefore apply to the WSDAs approach worldwide: can a generic set of competencies hope to satisfy a diverse range of engineering professions? Furthermore, can such statements apply not just to different engineering professions, but to engineering professions in different regions of the world which might have very diverse geographical, social, economic and political constraints, influences and imperatives? These questions were addressed as part of the semi-structured interviews and the discussion is presented in Section 4.4.

As has already been stated, UK BSE graduates often work abroad in countries under the WSDA umbrella and therefore come under the protection of the established protocols for mutual recognition of qualifications. As previously described, however, it is to be expected that as world economies and technologies continue to develop, that an increasing number of UK educated BSEs are likely to be working in countries outside these mutual agreements, sometimes where quite different economic and social imperatives influence the skillsets that engineers might be expected to command. Again, discussions on this subject are presented in Section 4.4.

2.8.2 The Bologna Process and EUR-ACE

The Bologna Process (BP) is a voluntary HE reform process currently involving 49 countries both inside and outside Europe, that aims to make HE systems compliant to enhance their international visibility and assist with international recognition of HE qualifications (EUA, 2017). The BP was not actually instigated by the European Union as is commonly believed; rather it was an inter-governmental initiative originating from four countries, namely France, Germany, Italy and the UK, which resulted in the Sorbonne Declaration of 1998. This committed the signatories "to encouraging a common frame of reference, aimed at improving external recognition and facilitating student mobility as well as employability", with the eventual objective of harmonising "the architecture of the European Higher Education system" (Wende, 2016). The following year, 1999, the BP was launched with 29 member countries, and the continuing process has since widened to include 49 countries inside and outside of Europe (ENAEE, 2017).

The simple motivation behind Sorbonne and the BP was a growing realisation that the variety of approaches evident within European HE, despite being a great asset to Europe's cultural background, was in practice a hindrance to mobility and transnational recognition of professionals both in Europe and worldwide (Augusti, 2005). The BP's initial aim then was to set up "a system of easily readable and comparable degrees" and to establish a European Higher Education Area (EHEA) by 2010 (Augusti, 2005). The key objectives at the outset were that European countries with different political, cultural and academic traditions would co-operate to ensure that European students and graduates would be able to move easily from one country to another with full recognition of qualifications and European governments would fit their national HE reforms into a broader European context. Furthermore, there would be transparency, co-operation, trust and confidence between European HEIs, facilitating the exchange of students and staff. This, it was argued, would increase the international competitiveness of European HE and improve cooperation with HE in other regions of the world (Benelux Bologna Secretariat, 2009).

The process achieved its immediate objectives, initiating the EHEA as planned, and it continues to carry out useful work with further targets set against a 2020 deadline. The aims of the BP and EHAE are now principally promoted by the EU through the Commission, Parliament and Council (EUA, 2017).

With particular reference to engineering education, Augusti (2006) reasoned that while academic qualifications and professional competencies could relatively easily be recognised across borders under the auspices of the BP, little progress was being made towards internationally transparent accreditation processes for educational programmes which are the entry route into many professions. He argued that highly internationalised professions like engineering needed a "pan-European system of accreditation" of programmes and qualifications to ensure the competitiveness of European engineers globally (Augusti, 2006).

The European Standing Observatory for the Engineering Profession and Education (ESOEPE) was established in 2000 and proposed the afore-mentioned EUR-ACE project in 2004. This proposal envisaged the establishment of a quality brand, the EUR-ACE label, which could be awarded to engineering degree programmes where certain educational standards had been attained. The EUR-ACE label attached to an academic programme indicates that the programme is accredited by an ENAEE member agency as a first cycle degree [equivalent to a UK BEng (Hons)], or second cycle degree (an integrated Masters equivalent to a UK MEng or MSc). The proposal was duly accepted by the EU Commission who provided funding for the project (ENAEE, 2011).

The establishment of the EUR-ACE system was concluded in 2006 and, having served its purpose, the ESOEPE was disbanded. The role of enacting and implementing the EUR-ACE project was then assumed by the ENAEE, together with 14 partners representing a wide range of stake holding organisations on behalf of both the academic and professional aspects of engineering education. Six of the partners were international associations or networks covering more than one European country, while the other eight were the accrediting bodies in member countries (France, Ireland, Germany, Italy, Portugal, Romania, Russia and the UK), all of whom were, and still are, participants in the BP. The EC is the UK body licenced to award the EUR-ACE label to accredited engineering degrees as meeting in part or in full the academic requirement for CEng registration (EC, 2014).

The standards that EUR-ACE applies are in effect a collection and harmonisation of existing standards from several European and global engineering accreditation agencies and bodies, and these are intended to form a framework for recognising accreditation bodies and endorsing accreditation procedures, a process that Augusti (2006) terms "meta-accreditation". The standards also act as guidance for countries to develop new operative standards where they do not currently exist (Haug, 2003).

The principles set out for accreditation procedures under the EUR-ACE banner are very similar to those set out under the EC and WSDA regimes, in that the accreditation philosophy is again output based. In a similar way to EC and WSDA standards, the accreditation process proposed under EUR-ACE is based on a peer review process, whereby programmes are periodically inspected and assessed against published standards, and these standards are likewise generic and apply to all engineering disciplines. The practice of national accrediting agencies appointing panels of independent academics and professional engineers to visit institutions and inspect courses is emulated, as is the practice of scrutinising individual programmes or courses rather than allowing blanket accreditation to whole institutions or departments (Augusti, 2009).

Eight programme outcomes are listed under the EUR-ACE standards (ENAEE, 2015):

- Knowledge and understanding
- Engineering analysis
- Engineering design
- Investigations
- Engineering practice
- Making Judgements
- Communication and Team-working
- Lifelong Learning

If it is considered that the final three outcomes in the list broadly equate to what might be collectively termed “transferable skills”, the parallels with the EC’s learning outcomes published in AHEP 3 are striking and very obvious.

The ENAEE claims that the EUR-ACE system encompasses all engineering disciplines, is widely recognised internationally and facilitates both academic and professional mobility (ENAEE, 2011). At the time of writing, the ENAEE had, since 2006, authorised 15 agencies to award the EUR-ACE label to 2,815 engineering degree programmes in around 300 HEIs in 38 countries both inside and outside of Europe (ENAEE, 2017). Closer inspection of the ENAEE database confirms that 12 UK universities run EUR-ACE accredited programmes, though none of these are in BSE. There are, however, EUR-ACE accredited BSE programmes in four institutions in Ireland and in four German institutions (ENAEE, 2017). Upon closer inspection of the Irish and German BSE degrees, these were found to have similar content and structure to UK courses, so it could certainly be argued that there is a consistency of approach encouraged by the ENAEE, and this very definitely resonates with the WSDA approach. Ireland is a full signatory to the WSDAs, while Germany was a provisional member until 2013, and then, as a leading EU member, elected not to pursue full membership and concentrate efforts on the ENAEE system. Germany’s withdrawal from the WSDAs certainly underlines a perception that the Accords constitute a system designed primarily for English speaking countries, though the two are most certainly not mutually exclusive.

Augusti (2009) suggests certain issues which will need to be addressed to secure the future success of EUR-ACE. The BP covers many more countries than EUR-ACE and thus inconsistencies of approach between disciplines will inevitably arise. Also, HEIs can be protective of their autonomy, and Augsusti (2009) notes that in many countries HEIs are not even obliged to recognise each-other's degrees, let alone qualifications from abroad. He further ponders the notion of a European Board of Engineering Accreditation, mirroring the role of ABET, the board which manages to harmonise the various systems found in the American states, as a means to steer the process further, though concedes that such a move could be immensely problematic (Augusti, 2009).

2.8.3 International licensing of engineers

Regulation and licensing of professional engineers is carried out by various jurisdictions in different countries across the world though, unsurprisingly, there is no universal agreement for licensing engineers across international boundaries (Kasuba & Ziliukas, 2004). Naturally there are a great many concerns: differences between education systems, differences in national engineering standards, differences in language and culture, determining the appropriateness, comparability and applicability of engineering experience, and differences in definitions of professional responsibilities and accountability can all become major issues. Most of these concerns are at present beyond the remit and reach of the WSDA and ENAEE systems, though these innovations do make honest and worthy attempts to effect some solutions to the identified concerns (Kasuba & Ziliukas, 2004).

The professional status of engineers and the actual practice of engineering are, as has already been stated, legally defined and protected by law in several national (and international) jurisdictions. In many cases this means that only appropriately licensed or registered engineers have legal authority to take responsibility for engineering work. This is particularly true in cases where public safety or welfare is concerned, though many jurisdictions permit engineers to work internally for a licenced organisation or company without personal licensure on the understanding that they are not making final engineering decisions.

The mobility of engineers and licensing for international practice are important for most, if not all, engineering disciplines and, in the absence of universal licensing agreements, attempts are being made to work with various international trade agreements to develop and maintain registers of engineers qualified to practice across border. The registers are, as would be expected, advisory and mutual recognition necessitates a case by case approach involving the regulatory bodies in each country (Shearman, 2010).

From a UK perspective, there are two main international registration categories that enable UK engineering registrants to practice overseas independently, and these are administered by the EC. Regulatory bodies in other member countries maintain these registers in their own jurisdictions.

- Chartered Engineers may apply for entry to the International Professional Engineer (IntPE) register via the International Professional Engineers Agreement (IPEA). The countries which are party to this agreement include Australia, Canada, Chinese Taipei, Ireland, Hong Kong, India, Japan, Korea, Malaysia, New Zealand, Singapore, South Africa, Sri Lanka, UK and USA. Bangladesh, Pakistan, Russia and the Netherlands are at present provisional members of the register (IEA, 2017d).

- Incorporated Engineers may apply for entry to the International Engineering Technologist (IntET) register. The countries party to this register include Canada, Hong Kong, Ireland, New Zealand, South Africa and UK, with Australia as provisional signatory (IEA, 2017e).

There is clearly a great deal of commonality between the lists of countries that recognise and maintain these registers and member countries of the WA and SA agreements.

A number of universities in countries that are not members of the WSDA agreements or the ENAEE seek international recognition or certification as a way to quality assure and market their courses. Accordingly, many institutions request the American Board for Engineering and Technology (ABET) to evaluate their engineering programmes according to ABET criteria. The ABET does not actually accredit programmes outside the USA, it does, however, provide an international review service, assessing courses for equivalency to ABET criteria. Because the USA is one of the lead signatories in the WA the influence and reach of the WA (and since it is so closely linked, the SA) is extended worldwide (Kasuba & Ziliukas, 2004).

In the USA, systems of compulsory licencing of engineers are in effect, though there are different systems evident across the different states, which makes licencing more complex than it should perhaps be. The systems and standards are, however, efficiently and effectively overseen by the ABET. Licensed professional engineers, however, only constitute about 20% of the US engineering workforce and much engineering work is carried out by unlicensed and unregulated technicians and technologists (Kasuba & Ziliukas, 2004).

It is, however, of benefit to consider the activities of the ABET since it has dealings in so many overseas mutual recognition initiatives. In an effort to assist and encourage licensed engineers in the USA to practice internationally, the United States Council for International Engineering Practice (USCIEP) was formed, of which ABET was a lead member. This body was, however, superseded by the National Council of Examiners for Engineering and Surveying (NCEES) in 2006, an organisation which now works with a number of overseas partners to explore the possibilities for licensing engineers under several trade agreements. The main trade agreements are:

- North American Free Trade Agreement (NAFTA), which involves Canada, Mexico and USA;
- Asia-Pacific Economic Cooperation (APEC), which was established in 1986 by 12 founding members: Australia, Brunei, Canada, Indonesia, Japan, South Korea, Malaysia, New Zealand, Philippines, Singapore, Thailand and the USA; since that time, the APEC accepted nine new members: Peoples Republic of China, Hong Kong, Taiwan, Mexico, Papua New Guinea, Chile, Peru, Russia and Vietnam;

- Transatlantic Economic Partnership (TEP), which involves the European Union and the USA (NCEES, 2016).

Thus it can be seen that American influence, and hence the influence of the WSDA agreements, is key to international reciprocal recognition of engineering qualifications, registration and licencing.

2.9 Chapter summary

It is evident that the approaches taken by the WSDA and EUR-ACE systems differ in flexibility and scope, but their principal aims of working towards international transparency of engineering qualifications, along with establishing high quality levels in accreditation and engineering education, are common. The similarities in aims of the two systems, plus the fact that many countries are members of both, indicates that the two approaches are not mutually exclusive and complement each other well (Kasuba & Ziliukas, 2004).

The WSDA and EUR-ACE arrangements do not deal with licensing of engineers, which would be carried out by responsible bodies in the member countries as discussed in Section 2.8.3 above. Notwithstanding the alternatives, The WSDA and EUR-ACE agreements would appear to be the leading force for the standardisation and mutual recognition of engineering competencies across the globe, and the list of nations subscribing to these is constantly growing.

Richard Shearman, Director of Formation and Deputy CEO of the EC, asserts that when considering mutual recognition of qualifications, the WSDA system is the most favourable with respect to the UK-SPEC, though he allows that the EUR-ACE system advanced by the ENAEE is also compatible (Shearman, 2009) & (Shearman, 2010). His view would underline the widely held belief that UK graduates and EC registrants enjoy every advantage possible with international mobility. Augusti (2009) claims, however, that the EUR-ACE system, compared with the WSDA system is simpler and more flexible. In particular he contends that EUR-ACE does not create a rigid barrier between “engineers” and “technologists” (which, he argues, as well as being undesirable, would in many languages actually not be understandable), and at the same time, EUR-ACE assimilates national differences between educational systems into a cohesive structure. Both systems continue to expand outside of what might be considered their natural catchment areas, and this seems set to continue (Kasuba & Ziliukas, 2004).

The EUR-ACE accreditation system championed by the ENAEE is undoubtedly a major force for good in the international alignment of engineering courses and its work does not in any way contradict or compromise the WSDA agreements. The main difference, however, is that EUR-ACE does not seek to encourage mutual recognition of professional engineering competencies as the WSDA agreements do, its remit at present is only to harmonise engineering qualifications and national accreditation systems in member countries (Wende, 2016).

In the field of BSE, as has already been reported, the most common overseas destinations tend to be WSDA countries. There is far less migration to European destinations, due undoubtedly to language difficulties and British Commonwealth loyalties, but also due to what are perceived as different procedures and protocols apparent in EU countries. For instance, it is widely believed (for the most part mistakenly) that

UK CEng qualified engineers must hold the EurIng title to work in other EU countries, and this appears to constitute a further barrier. As has been inferred in these discussions, the accreditation of BSE courses may be addressed with a degree of consistency under both the WSDA and ENAEE approaches to international mutual recognition, however the EUR-ACE badge has only been adopted by eight institutions worldwide (four in Eire and four in Germany) delivering BSE courses.

As already discussed, the USA's undertaking via ABET is to provide an international advisory service to compare engineering academic courses and accreditation systems against ABET standards, and since the USA is a leading signatory and enthusiastic promoter of the WSDA agreements, it thus indirectly further promotes these accords and their ethos. The EC's approach is, as previously noted, to define professional competencies and influence educational qualifications from a national perspective, and from this position to work towards international mutual recognition of engineers through the WSDAs and other international agreements.

Other mutual recognition systems seen through the world operate under the auspices of the IEA, and these include the Asia Pacific Economic Cooperation Engineer Agreement (APECEA), The International Professional Engineer Agreement (IPEA) and the International Engineering Technologist Agreement (IETA). Significantly, these agreements deal only with professional engineering competencies and not educational qualifications and they also thus do not incorporate the wider sphere of influence of the WSDA agreements.

As stated, the ENAEE's approach is restricted to the accreditation and reciprocal recognition of engineering courses in member countries, whereas the WSDA agreements deal also with recognising professional competencies achieved in the workplace, which lead to the registration of engineers in the various jurisdictions across the world. Therefore, as this work progresses towards the development and synthesis of a new education and training model to facilitate international mobility of UK BSE graduates, it focusses more on the EC and WSDA approaches and does not consider the EUR-ACE system further.

With this in mind, it is therefore important to investigate whether BSE degrees awarded by UK universities and other worldwide institutions operating within the WSDA framework actually equip graduates with the best possible skillset necessary for the international arena both inside and outside the umbrella of WSDA countries. An issue which has been explored in the data collection part of this thesis is the possibility that the use of generalised statements of engineering competence, as seen in the EC and WSDA approaches, are written largely from a Western cultural viewpoint. For course accreditation purposes and for engineer registration it must be assessed whether this could be in any way unhelpful to international transparency and mutual recognition of engineering qualifications. In addition, the EC and WSDA approaches to engineer registration concentrate on professional competence demonstrated in the workplace, while many countries consider only academic achievement. These factors undoubtedly affect the international mobility of BSE graduates and must be considered in the synthesis of a new education and training model to facilitate internationalism.

Chapter 3 – Research Methodology and Data Collection Techniques

3.1 Scope and content of chapter

This chapter discusses and justifies the choice of data collection techniques and methodologies employed in this work, and shows how these link to the main research aim and specific objectives. The methodologies to be utilised are described at the start of the chapter to assist the reader in appreciating the successive phases of the work and the overall storyline.

Once the methodologies have been summarised, the reasons behind the selection of these methodologies are examined in some detail. The philosophical position of the research is considered in the first instance and this leads on to defining the research approach and an examination of the methods available and a justification of those utilised. The chapter concludes with an overview of the ethical position of the research.

It must, however, be stated that no methodological approach can ever be completely free from shortcomings, but the available methodologies and data collection techniques that are feasible for this kind of subject matter have been explored as exhaustively as possible in a best attempt to exclude potential weaknesses. Any methodological inadequacies that become evident at the conclusion of the project will, however, be evaluated in the context of the project findings and conclusions. It is anticipated that being clear on the methodology and measurement techniques will engender confidence in the project itself.

3.2 Research methods utilised in this work

Due to the nature of the research question, a pragmatic research approach has been selected, since this allows the researcher not to be constrained and ''be the prisoner of a particular [research] method or technique'' (Robson, 1993). Denscombe (2008), advocates mixed methods to "produce a more complete picture, to avoid the biases intrinsic to the use of mono method design, and as a way of building on, and developing, initial findings". Saunders et al (2015) suggest that a combination of quantitative and qualitative methodologies alongside an abductive research approach can work well with this kind of study to provide an in-depth understanding of the research topic at each stage prior to the commencement of the next stage. Creswell (2013) also concurs that a mixture of methodologies such as this can be appropriate to extend and contextualise knowledge and refine understanding at each stage by exploring the research question with individuals and groups.

This study therefore adopts a multilevel, sequential mixed methods approach, since it seeks to gain initial knowledge from literature and an exploratory round of semi-structured interviews, this leading onto a questionnaire survey, then to a further series of semi-structured interviews which all go to inform the synthesis of an education and training model for BSE. Finally, the model is then tested using a concluding round of semi-structured interviews.

The different methods are used to inform and supplement each other, each method addressing a different layer of the research topic. This work was divided into four distinct (though necessarily overlapping) phases summarised in Figure 7 below:

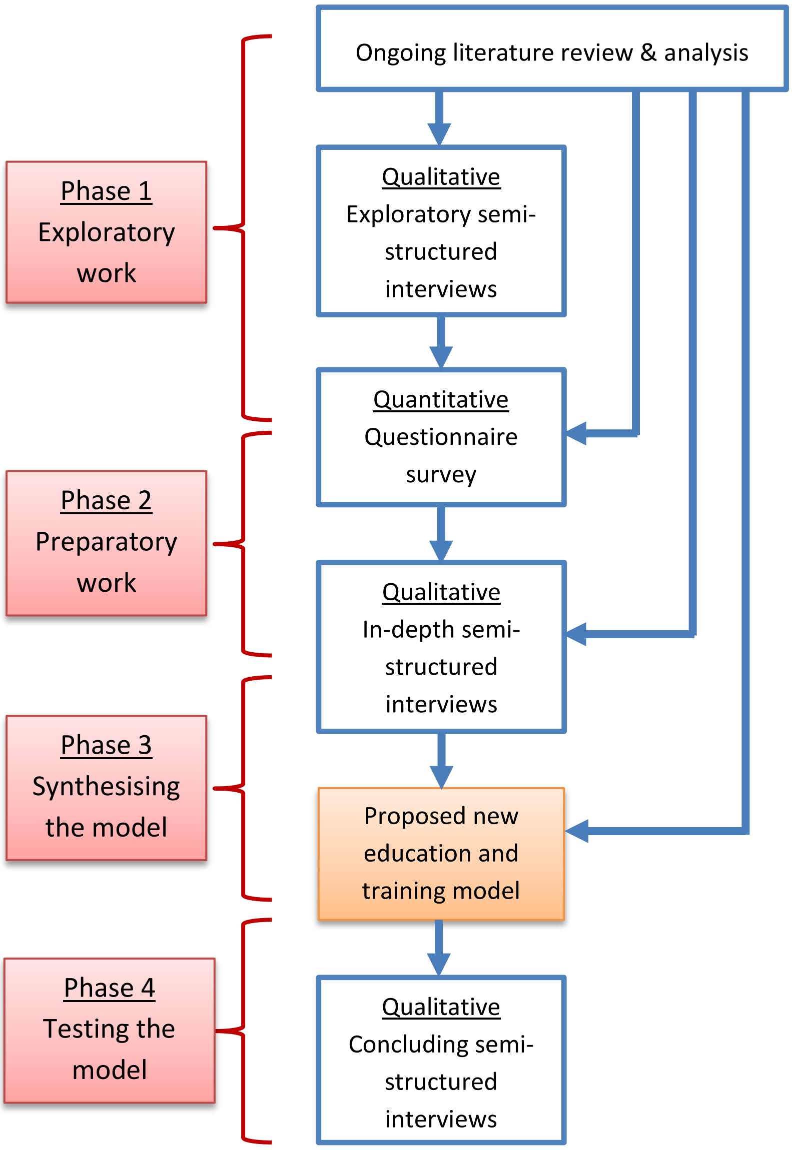

Figure 7 Methodologies adopted in this research

Phase 1 – Exploratory work

The study commences with an examination of the literature available on education and training in Engineering and BSE, the formation and roles of the PEIs (particularly the CIBSE) and the EC, the history of the UK-SPEC, engineer registration and professional memberships. A small number of exploratory semi-structured interviews were then used in the context of the literature review, to inform the subsequent phase of research.

Phase 2 – Preparatory work

A questionnaire survey, targeted at staff members of the 35 PEIs, was circulated to assess the background behind the development of the UK-SPEC, the PECs and examine views and opinions about the processes of engineer registration and course accreditation. The literature review continued in the light of previous work, exploring such issues as accreditation of academic courses in the UK and overseas and worldwide recognition of UK engineering competencies. Quantitative data collected from the questionnaire was then used alongside qualitative data obtained from the ongoing review of literature to construct the questions for a further round of semi-structured interviews.

Phase 3 – Developing and Synthesising the education and training model

A wider round of in-depth semi-structured interviews was carried out to establish further qualitative data. The literature review continued, exploring definitions of competence and relating this to the design of academic courses in engineering generally and BSE in particular. The data gleaned from the interviews, alongside those obtained from the questionnaire and ongoing literature review were used to inform the development and synthesis of a proposed internationalist education and training model for BSE.

Phase 4 – Testing the education and training model

A further smaller and more intensely focussed round of in-depth semi-structured interviews was carried out to test the proposed education and training model. From this a series of conclusions were drawn as to the suitability of the model and avenues for further work were inferred.

A mixed methodology has been employed in this work where both qualitative and quantitative data have been collected and analysed. It is essential to consider the methodologies and data collection techniques that address each of the research specific objectives.

Table 9 below summarises the methodologies used to address each objective.

Table 9 Summary of research methods used in this work

Specific objective		Literature review	Questionnaire survey	Exploratory semi-structured interviews	In-depth semi-structured interviews	Concluding semi-structured interviews
1.	Examine the development of the EC and PEIs and critically review their influence on BSE academic programmes and qualifications.	x		x		
2.	Investigate the introduction of the UK-SPEC and critically review the EC's approach for making judgements about the accreditation of academic programmes and registration of engineers.	x	x	x		
3.	Critically evaluate the membership details of the PEIs and critically review the EC registration grades and PEI member categories.	x	x			
4.	Examine how BSE study programmes are developed and the process of professional accreditation in the UK.	x	x		x	
5.	Examine the educational and professional requirements for engineers to be registered to practise in the UK and overseas.	x			x	
6.	Investigate and critically analyse international systems which are attempting to facilitate international transparency of engineering qualifications.	x			x	
7.	Compare and contrast the main systems and procedures overseas for accrediting engineering academic programmes, recognising engineering competencies and registering/licencing engineers.	x			x	
8.	Elicit views as to the perceived value of a UK engineering education when practising abroad.				x	
9.	Elicit views about what an education and training model should encompass to facilitate internationalism in BSE education.				x	x
10.	Synthesise and critically evaluate an education and training model to promote internationalism in BSE.					x

3.2.1 Literature review and analysis

Bryman (2012) suggests that the need for a literature review in any research project is to ensure that the researcher knows what is already known about the subject area so that poorly conceived questions covering unnecessary material are not asked during the data collection processes. The literature review in this work initially sets out the scope of the research field, then moves on to describing the way that BSE education and training currently works, examining existing knowledge in the field and identifying deficiencies, and into the international arena. Review and analysis of literature was necessarily ongoing while other research methods were underway, and therefore feeds into the first three phases of the research as indicated in Figure 7 above.

To begin with, the literature review was instrumental in addressing the first four objectives in this work:

Objective 1 *– Examine the development of the EC and PEIs and critically review their influence on BSE academic programmes and qualifications.*

Objective 2 *– Investigate the introduction of the UK-SPEC and critically review the EC's approach for making judgements about the accreditation of academic programmes and registration of engineers.*

Objective 3 *– Critically evaluate the membership details of the PEIs and critically review the EC registration grades and PEI member categories.*

Objective 4 *– Examine how BSE study programmes are developed and the process of professional accreditation in the UK.*

To appreciate the influence of the EC on BSE academic programmes and qualification it was necessary to summarise the modern developmental history of the EC and PEIs. The narrative describes how the development of these bodies led to the introduction of the UK-SPEC and AHEP 3 as a way of ensuring that academic courses prepare students to enter careers in engineering. To gain insight into the value placed upon professional registration and membership of PEIs some critical evaluation was carried out into the membership profiles of the PEIs. Following this, the processes and philosophies of accreditation of academic programmes were critically reviewed.

The literature review established specific features in the field of UK engineering education, qualification and registration to enable the exploratory semi-structured interviews to be devised and also informed the subsequent development of the questionnaire survey.

Once some initial data had been gained from the exploratory interviews the parts of the literature review dealing with objectives listed below were relevant to implement the in-depth semi-structured interviews.

***Objective 5** – Examine the educational and professional requirements for engineers to be registered to practise in the UK and overseas.*

***Objective 6** – Investigate and critically analyse international systems which are attempting to facilitate international transparency of engineering qualifications.*

***Objective 7** – Compare and contrast the main systems and procedures overseas for accrediting engineering academic programmes, recognising engineering competencies and registering/licencing engineers.*

The process of registration of engineers in the UK was considered in light of differing practices in other parts of the world and the process of international transparency of qualifications was examined. As part of this process, the UK method of course accreditation was compared with common overseas systems and some in-depth analysis was carried out into the WA, SA and EUR-ACE systems.

3.2.2 Questionnaire surveys

The technique of using questionnaire surveys supports pragmatic work and is one of the methods adopted by this research in its mixed methods approach. The use of questionnaires is normally associated with a deductive research stance, and is one of the most popular methods since it allows data to be collected from a large population in an efficient and economical way (Saunders, Lewis, & Thornhill, 2015). Questionnaires are perhaps the least intrusive of data collection methods when dealing with human subjects, since a questionnaire can be very easily and efficiently circulated electronically, and online surveys can guarantee anonymity of participants, which tends to encourage honesty and openness in responses. Electronically managed questionnaires also have the advantages of providing the researcher with a speedy means of collecting data.

However, it can also be argued that quantitative data provided by questionnaires may miss underlying meaning and explanations and provide only a snapshot at a moment in time (Amaratunga, Baldry, Sarshar, & Newton, 2002). There is also a lack of personal contact which may lead to low-quality responses, though good design, wording, sequence and structure of the questionnaire can alleviate this. In addition, there is a possibility that if some respondents lack confidence in the research, they may not respond honestly or may fail to respond at all. It is hard for the researcher to quality assure participants’ answers and there is usually no way to ask follow-up questions.

Stone (1993) advises that a good questionnaire should be self-validating; questions should concern facts and knowledge, and must be intelligible, unbiased and unambiguous, while possible responses must be guided towards a useable form. Stone (1993) further states that questionnaires should be piloted before being put to formal use. Kumar (2014) adds that when designing the questionnaire, the sample, the topic, the layout and length of the document, and the quality of information provided to participants explaining the topic, all need to be given due consideration.

Stone (1993) suggests 10 steps to designing a functional questionnaire:

1. Decide what data you need
2. Select items for inclusion
3. Design individual questions
4. Compose wording
5. Design layout
6. Think about coding
7. Prepare first draft and test
8. Pilot and evaluate
9. Perform survey
10. Start again!

Choi & Pak (2005) advise of the errors that are possible due to bias in questionnaires, and suggest that to collect the most accurate data from respondents, researchers must understand and be able to minimise this in the design of questionnaires. Choi & Pak identified (2005) catalogue three commonly identified forms of bias in questionnaire design:

1. Issues with wording – questions that are ambiguous, complex, too short or two long, (over)use of jargon, vagueness or over-complexity of language.
2. Missing or inadequate data for the intended purpose – incorrect measurement methods, faulty scale and format, missing or overlapping intervals.
3. Poor question framing – leading questions, inconsistent style of questions, sensitive questions.

These issues were fully considered in the design of the questionnaire survey used in this research. Questions were designed to be non-leading, they were framed as clearly and unambiguously as possible, they were kept (as far as possible) free from jargon, and were stated as briefly as possible while still providing sufficient information for their purpose. In addition, the questionnaire was piloted before use as advocated by Fellows and Liu (2015).

When seeking participants' respective individual positions on questions where a range of opinion may be possible, there are various techniques in which responses may be measured or scored, including listing, ranking and rating (Saunders, Lewis, & Thornhill, 2015). The Likert scale is one such method, and this enables attitudes of the participants to be established by presenting a list of statements declaring specific attitudinal or emotional positions and asking respondents to rate these in terms of agreement or disagreement (Sekaran, 2003). The Likert scale also incorporates a neutral option for when participants do not have a particular opinion or emotional stance on a question, and this technique is claimed to minimise bias (Sekaran, 2003). There is, however, some disagreement among researchers as to an appropriate number of scale points on the Likert scale, though normally a scale of five or seven points are used with the neutral response being the central value (De Winter & Dodou, 2010). For example, a question may make a statement and then invite respondents to agree strongly, agree generally, neither agree nor disagree (the neutral response), disagree generally, or disagree strongly with the statement. A numerical score can be assigned to each response to enable quantitative analysis. Some commentators, for instance Johns (2005) and Krosnick et al (2002), contend however, that the neutral response can provide respondents with an easy way to not consider difficult or awkward questions and may therefore constitute a substantial weakness in the questionnaire. This is particularly true for very large samples where the questionnaire is circulated very widely, and by extension, potentially indiscriminately. In this particular research project, however, the questionnaire survey was aimed at a selected discrete population who would most certainly be familiar with the subject matter, therefore it was considered that the participants could realistically hold a neutral point of view, an approach advocated by Dillman et al (2009). In this research a five point Likert scale with a neutral position is adopted in several of the survey questions.

Before a questionnaire is distributed generally, it is good practice to carry out a small pilot study: the questionnaire should be completed by a small sample of respondents to check its quality and applicability, and ensure that questions are intelligible and unambiguous. Feedback from this process enables the researcher to revise and improve the questionnaire if necessary (Fellows & Liu, 2015).

Normal present-day practice is to circulate questionnaires using email systems (Miles, Huberman, & Saldaña, 2009). This can either be the circulation of an electronic file requiring the respondent to download, complete and return, or more commonly, a link to a website where an online questionnaire is hosted. Online surveys, which have become standard practice over recent years, prove extremely convenient for respondents since they allow immediate access without the imposition of downloading or saving any documents, and furthermore they allow responses to be stored centrally and can interface with statistical analysis software, thus reducing the researcher's data management load. In addition, the "snowball effect" of social media is increasingly being used by researchers to circulate questionnaires more widely, and this method delivers the added benefit of providing online fora for participants and the researcher to interact (O'Leary, 2012).

3.2.3 The questionnaire strategy adopted by this research

The questionnaire in this research was designed to address the following the research objectives.

Objective 2 *– Investigate the introduction of the UK-SPEC and critically review the EC's approach for making judgements about the accreditation of academic programmes and registration of engineers.*

Objective 3 *– Critically evaluate the membership details of the PEIs and critically review the EC registration grades and PEI member categories.*

Objective 4 *– Examine how BSE study programmes are developed and the process of professional accreditation in the UK.*

The survey was developed using the Bristol Online Survey (BOS) tool, which allows the researcher to develop, distribute, and analyse surveys online.

A structured questionnaire focussing on the research objectives, with closed questions was selected as being the most appropriate for this research, since specific closed questions are most likely to prompt a valid response. However, to obtain more nuanced views, follow up questions inviting further comment in a free text box were appended to the closed questions where further qualitative information could be useful. The closed-ended questions required the respondents to select an answer from a number of mutually exclusive options and the respondent's answers then generated data which could subsequently be analysed quantitatively for trends and patterns to be inferred, and the free text comments could be analysed qualitatively for deeper understanding and insight.

The questionnaire for this research was piloted with three members of academic members of staff, who are established researchers, at Liverpool John Moores University, and two senior staff members at the CIBSE. Following the pilot, the following amendments were made:

- The wording of some questions was amended to aid clarity.
- One question, asking for detailed information about membership numbers of the PEIs was simplified as its ease of answering was (quite rightly) questioned, and such data is in any case readily available in EC publications.
- The acronyms used in the questions were fully explained.
- Notes were added at the beginning and end of the questionnaire explaining the questionnaire's purpose and how the data would be used.

The pilot study indicated that the questionnaires took between 10 to 15 minutes to complete, which the pilot respondents felt was acceptable. After making the amendments indicated above, the questionnaire was circulated to PEI staff members via email with a covering letter (approved by the university's ethics committee).

A purposive form of strategic sampling in combination with a quota and snowball strategy, as advocated by Bryman (2012), was adopted to distribute this questionnaire (see Section 4.1 for discussions on sampling strategies). The purposive sample in this case comprised of staff members who deal with membership, registration of engineers and accreditation of academic courses at the 35 PEIs. The questionnaire was therefore sent via email to staff members at each PEI, and the email provided details of the aims and objectives of the research and a hyperlink connecting them directly to the online survey. The snowball strategy employed was a request that the questionnaire be forwarded to the staff members' colleagues. The quota sample required at least one response from each of the 35 PEIs, and where a response was not forthcoming, follow-up emails and telephone calls were made. A total of 82 valid responses were received.

The questionnaire was divided into four sections to help in the organisation of the research variables.

Section 1 - Personal and Institutional Details

This section focusses on eliciting data about the respondents in relation to their job title, job roles and experience working in PEIs. This was important for providing basic data for the project about the individuals completing the survey. Since the PEIs differ so widely in size, and the research project aims to establish the relative influence of the PEIs in EC matters, it was necessary to establish the level to which the smaller PEIs rely upon volunteer staff. When looking at opinions on the UK-SPEC and the drafting of the PECs it is helpful to have a perspective of the relative experience of PEI staff, hence there are questions relating to length of service.

Section 2 – Interaction with other PEIs and with the EC

This section asks questions about the amount of contact that staff members have with other PEIs and with the EC itself, before going on to elicit views about how representative respondents feel the EC is with respect to the various engineering disciplines.

Section 3 - The UK-SPEC and entries to the UK Register of Engineers

This section elicits views as to the consistency of engineer registration processes across the PEIs. Some of the literature implies that there is potential inconsistency so it is important to establish whether this is in fact likely to be the case. This could have a direct effect on the establishment of an internationalist education and training model.

Section 4 - Accreditation of Higher Education courses

Again the questions in this section attempt to elicit views about inconsistency across the PEIs, this time in relation to accreditation of academic courses. Again, this could directly affect the development and synthesis of an internationalist education and training model.

The questionnaire survey is reproduced in Appendix 4.

3.2.4 Individual interviews

Interviews are commonly considered to be a well-established tool in qualitative research, which can be utilised at any point in the data collection process, independently or in tandem with other techniques (Brewerton & Millward, 2001). An interview consists of a professional conversation where knowledge may be analysed and even created during the interaction, and Kvale (2007) considers that much of the analytical work may actually occur during the interview process where the researcher clarifies understanding and interpretation of knowledge with the interviewee. Numerous other commentators support these assertions and identify interviews as being one of the most widely adopted qualitative research methods (Dainty, 2008) (Amaratunga, Baldry, Sarshar, & Newton, 2002).

Interviews may be fully structured, semi-structured or unstructured, though the most commonly used type used is the semi-structured interview, where a general framework is laid down by the researcher and during the interview process, the interviewee is allowed (even encouraged) to deviate in a controlled and measured manner from the framework, such that additional supplementary knowledge and views are obtained. Such an interview technique has the advantage of maintaining a degree of objectivity, because a structured framework is followed for each interview in a particular set, while still facilitating a more thorough understanding of each interviewee's knowledge and opinions (Amaratunga, Baldry, Sarshar, & Newton, 2002). This view is disputed by some, who argue that in poorly conducted semi-structured interviews, the researcher does not have sufficient opportunity to understand how participants themselves structure the research topic, and too much structure can stifle variation in responses (Bogdan & Biklen, 1992). Despite these reservations semi-structured interviews are the most frequently used form of interviews in research of this type (Fellows & Liu, 2015).

Interviews can be “in-depth” or “exploratory” in nature. Exploratory interviews with individuals with experience and knowledge relating to the research question can be used to offer new dimensions and ideas, help to develop hypotheses, and refine the initial research question. Oppenheim (2000) argues that the exploratory interview is principally experimental in nature and need not be used to gather facts and statistics; rather it should be a tool to develop ideas and hypotheses. A small number of exploratory interviews were therefore used at the beginning of this research to refine the research question, research aim and specific objectives, as well as to assist with the development of the data collection methods to be used later.

Interviews may be carried out as face to face meetings, using video conferencing, as telephone conversations, or through internet based chat fora. There are several publications dealing with a range of views about which techniques are most effective and/or expedient, though it is possible to find publications broadly supporting all methods. All may therefore be considered equally valid if used appropriately.

Creswell (2009) considers face to face interviews to be preferable, though concedes that this is not always feasible or possible. The telephone is of course a widely accepted means of everyday communication in both business and private settings and, despite the obvious drawback of not being in close proximity to the interviewee, can be useful when face to face interviews are not possible. Some would even argue that there are advantages to be had when using telephone interviews over face to face meetings: where long distances are involved, telephone interviews are a cheap and expedient method (Hash, Donlea, & Walljasper, 1985). Saunders et al (2015) further suggest that the telephone (and internet chat applications) may offer potential advantages when collecting sensitive information, since participants tend to perceive that communicating in a non-direct manner offers a modicum of anonymity. However, there are also warnings that using the telephone may lead to issues of reduced reliability where the participants are less willing to engage in a longer exploratory discussion: to be effective the researcher must gain the trust of participants, and establish their integrity, capability and credibility (Saunders, Lewis, & Thornhill, 2015).

There have been many studies concerned with the appropriate duration of an interview. Burke and Miller (2001) recommended that a duration of between 15 and 20 minutes is optimum, however, Cachia and Millward (2011) suggest participants are generally willing to engage in telephone interviews up to one and half hours if they are sufficiently motivated and rapport has been successfully established.

The method selected to record interviews is also important in determining quality of outcomes. Saunders et al (Saunders, Lewis, & Thornhill, 2015) suggest that it is good practice to use audio recording when conducting an interviews, particularly those conducted by telephone. Recordings can subsequently be fully transcribed or notes can be made of main points. Kvale (2007) advises that the style of transcribing is dependent on the purpose of the interview: if a transcript is required for sociolinguistic or psychological reasons, a verbatim style is necessary, whereas for general research note taking is sufficient. The interviews (face to face and telephone) in this research were digitally recorded with the participants' consent using a mobile telephone, and extensive notes were extracted shortly afterwards; a full transcript of the interviews was not considered necessary since the audio recordings could be referenced at will during the data analysis process. In cases where face to face meetings were not possible and video conferencing was offered instead of a telephone interview, all respondents in this study opted for a telephone conversation.

3.2.5 The interview strategy adopted by this research

Kvale (2007) suggests that for qualitative studies of this type a total of between 5 and 25 interviews would normally be indicated. In this research 22 semi-structured interviews took place in three sets: four exploratory interviews were carried out at the early stage of the research alongside the initial literature reviews, 14 in-depth interviews took place following analysis of the data received from the first set of interviews, from the questionnaire (discussed above) and further review of literature, and four further interviews were convened to test and validate the proposed education and training model and act as a guide for further work.

Exploratory interviews

The first set of exploratory interviews was designed to address the first two specific objectives:

Objective 1 *– Examine the development of the EC and PEIs and critically review their influence on BSE academic programmes and qualifications.*

Objective 2 *– Investigate the introduction of the UK-SPEC and critically review the EC's approach for making judgements about the accreditation of academic programmes and registration of engineers.*

The participants at this stage were all known to the researcher in a professional capacity and hence this avoided the issues of trust, credibility and competence identified earlier. The participants were:

- One senior member of CIBSE staff with knowledge of accreditation and registration and membership;
- One senior member of IET staff with knowledge of accreditation and registration and membership;
- Two BSE industry experts and practitioners, both Chartered Engineers, one a CIBSE member, the other a member of the CIPHE.

Prior to each interview the participants were provided with information outlining the details of the research and a consent form as required under the university's code of ethics. The interviews lasted from 40 minutes up to one hour and consisted of a series of open questions, allowing the interviewees to volunteer as much information and opinion as possible. A flexible and conversational style of interview was used in order to develop a rapport with the participant and elicit as much useful information as possible. These interviews sought to examine the initial part of the research question concerning the EC's influence on BSE education and qualification in the UK, and the participants were used as a means of exploring the direction in which the research could usefully progress, and to enable themes and patterns to develop for further exploration in the questionnaire and subsequent interviews.

The participants in the exploratory interviews were located in London, Hertfordshire, Manchester and Liverpool, thus, for the convenience of the participants, and to overcome the constraints of geography, the telephone was used for these interviews. This method offered a minimum of intrusion into the working lives of busy professionals, who were provided in advance with all the information concerning the interview, with expectations of what the conversation would encompass, and were given several choices as to the scheduling of the interview.

Following the exploratory interviews, the questionnaire described above was developed and circulated. Data received from the questionnaire and the ongoing literature review was used to determine the questions to be asked in the second round of interviews.

In-depth interviews

The second round of interviews were intended to address objectives 4, 5, 6, 7, 8 and 9:

Objective 4 *– Examine how BSE study programmes are developed and the process of professional accreditation in the UK.*

Objective 5 *– Examine the educational and professional requirements for engineers to be registered to practise in the UK and overseas.*

Objective 6 *– Investigate and critically analyse international systems which are attempting to facilitate international transparency of engineering qualifications.*

Objective 7 *– Compare and contrast the main systems and procedures overseas for accrediting engineering academic programmes, recognising engineering competencies and registering/licencing engineers.*

Objective 8 *– Elicit views as to the perceived value of a UK engineering education when practising abroad.*

Objective 9 *– Elicit views about what an education and training model should encompass to facilitate internationalism in BSE education.*

Because of the wide ranging nature of these objectives, a correspondingly wide range of respondents was selected, though the same interview questions and structure were utilised in each case. Some respondents, by virtue of their profession had more knowledge and held stronger opinions about certain aspects than others; this was expected and the interview processes were managed accordingly. The interviewees were as follows:

- Three members of academic staff, specialising in BSE and AE at three different UK universities, one of whom is an Iraqi national educated in Iraq, were interviewed. Two of these interviews were carried out by telephone and one face to face. These respondents were expected to be able to provide rich factual data and informed opinions covering particularly objectives 4 and 5. Because all three respondents were very experienced in a university environment, all were members of the CIBSE, one an IEng registrant and two CEng registered, it was also expected that they would be able to articulate valid views concerning objectives 6, 7, 8 and 9.

- Three senior members of academic staff, specialising in BSE related engineering disciplines overseas were interviewed, one practising in Australia, one in Sri Lanka and one in Hong Kong. Two of these interviews were carried out face to face when the researcher visited Sydney and Colombo, and the Hong Kong respondent was interviewed by telephone (video conferencing was offered in respect of the Hong Kong interview, but the interviewee preferred to use the telephone). These interviewees were expected to be able to contribute knowledge and informed opinions concerning objectives 5, 6, 7, 8 and 9. It was not expected that significant data relating to objective 4 would arise, though all questions were asked to ensure consistency of approach.

- Three senior practising BSEs with overseas experience were interviewed: one Lithuanian national now practising in the UK as an Incorporated BSE, one UK educated Incorporated BSE practising in Australia, and one Hong Kong educated Chartered BSE practising in Hong Kong. All three of these interviews were carried out by telephone, again video conferencing was offered as an alternative but none of the respondents appeared comfortable with the practicalities of this medium. These interviewees were expected to contribute knowledge and valid opinions concerning objectives 5, 6, 8 and 9. It was not expected that significant data relating to objectives 4 and 7 would emerge, though the questions were asked for the sake of consistency.

- Two senior BSEs, one of whom is a Chartered Engineer, the other an Incorporated Engineer, both of whom were educated in the UK and are currently operating in UK BSE consultancies, were interviewed. Both were selected based on their substantial experience of working overseas and employing overseas graduates, and both interviews were carried out by telephone. These interviewees were expected to contribute knowledge and valid opinions concerning objectives 5, 6, 7, 8 and 9. It was not expected that significant data relating to objective 4 would emerge, though the questions would be asked.

- Three senior members of staff at PEIs were interviewed, including one from the CIBSE, one from the EI and one from the IET. All three were selected based upon their long experience of working full-time with the UK-SPEC and their understanding of the Washington and Sydney Accords, and in one case extensive experience with and knowledge of the EUR-ACE system. These interviewees were expected to contribute expert knowledge and informed opinions relating to all the objectives listed above.

The participants for these interviews were either already known to the researcher in a professional capacity or were introduced to the researcher by interviewees at the exploratory stage of the work. A similar protocol was followed as for the exploratory interviews in that the participants were provided with information outlining the details of the research and a consent form. The interviews lasted between 20 minutes and one hour, consisting of a series of open questions, allowing the interviewees to volunteer as much information and opinion as possible, using the same conversational style as previously. All respondents were also invited to make further comment by email should they so wish, and indeed several did so.

Concluding interviews

A small and more focussed final round of four semi-structured interviews was arranged to address objective 10, to test the validity and utility of the proposed education and training model, and also to revisit objective 9.

Objective 9 *– Elicit views about what an education and training model should encompass to facilitate internationalism in BSE education.*

Objective 10 *– Synthesise and critically evaluate an education and training model to promote internationalism in BSE.*

Two respondents who had participated in the first round of interviews were selected again due to their excellent understanding of the research question, their level of interest in the project, their outstanding contributions to the previous interviews, and to ensure continuity in the final phase of the work. Two other interviewees were selected based upon recommendation of interviewees in the previous round of interviews. The respondents were therefore as follows:

- Two senior PEI staff members who have unique experience of working with the EC, WSDA and EUR-ACE accreditation systems.
- Two members of university academic staff, currently practising in UK, though with substantial experience of working in overseas universities.

A similar protocol was followed as for the previous interviews in that the participants were provided with information outlining the details of the research and a consent form. The interviews at this stage lasted in all cases around 30 minutes. The same interview approach was used as previously, a series of open questions relating to the specific objectives were asked using a conversational style, allowing the interviewees to volunteer as much information and opinion as possible. All respondents were also invited to make further comment by email should they so wish, and all expressed a wish to view and comment upon working drafts of the work, and a wish to read the final thesis.

3.3 Research purpose and philosophy

It would seem self-evident that, for any piece of research work, the purpose and focus of the research must be clearly identified (Creswell, Hanson, Clark-Plano, & Morales, 2007). There are of course many understandings of what kind of activities constitute proper academic research; Ghauri & Gronhaug (2010) offer a useful definition in the context of this work, that research can be considered to be the process of developing and performing an investigation in order to develop strategies that enrich or add to existing knowledge. Enhancing an existing knowledge base must be the objective of any reputable research and this aim is, without doubt, beneficial to human endeavour. Blaikie (2009) further considers that research can be characterised as having one of several key purposes: to describe, to explain and understand, to effect change, to predict, to evaluate or to assess impacts, or a combination of these.

The goal of this particular research project is to develop a strategic approach to the synthesis of an education and training model for BSE education that encourages internationalism, synthesise this model, and to carry out evaluations and assessments of the utility of such a model. It therefore sits within the definitions offered above.

It is generally accepted that the term "research philosophy" offers an overview of the merits and demerits of various research methodologies, and seeks to connect the development of knowledge and the nature of that knowledge to the main research question. There are certain well recognised philosophical standpoints to which researchers often ally themselves, for example researches may see their methodology as "positivist" in nature, as opposed to "interpretivist", and data collection methods are often considered to be "quantitative" as a distinct contrast to "qualitative" (Saunders, Lewis, & Thornhill, 2015). However, it is also suggested that it can be beneficial to adopt a multi-dimensional set of continua as an overall research philosophy rather than restrict oneself to distinct, mutually exclusive positions (Niglas, 2010).

The many diverse approaches must be considered at an early stage in any research work since, argues Easterby-Smith et al (2002), since a failure to understand and think through philosophical issues can have a detrimental effect on the quality of discussions and conclusions. Making appropriate reference to research philosophies before embarking on any detailed work helps to identify the type of evidence required, how this evidence should be collected, and how it should be interpreted to answer the research question. Correctly identifying the philosophical stance of any research can sometimes, at the outset, enable the research questions and objectives to be refined and adapted in ways that may not have been obvious in the particular research area where the researcher is operating (Easterby-Smith, Thorpe, & Lowe, 2002). Cresswell (2009) further observes a clear relationship between the design of the approach used to address the research aim and objectives, and the various types of scientific investigation methods that are feasible, given the nature of the work. Cameron and Price (2009) concur that due consideration of established research philosophies enables researchers to properly appreciate, understand and interpret the data that they gather, and this in due course enhances the accuracy of the research.

Research philosophy is said to consist of a theoretical perspective informed by the two properties of ontology and epistemology (Crotty, 1998). Grix (2010) also affirms that ontology and epistemology are the foundations upon which any research must be built. It can be argued therefore that the researcher's ontological and epistemological assumptions inform the choice of methodology and methods of research.

3.3.1 Ontology

Creswell (2013) and Denzin & Lincoln (1998) consider that ontology is a way of examining the nature of reality, focussing on what exists, relating this to the characteristics of the real world, and constructing a new reality based on this. Saunders et al (2015) identify two aspects of ontology, the first being objectivism and the second subjectivism.

Objectivism represents "the position that social entities exist in reality to, and independent from, social actors" (Saunders, Lewis, & Thornhill, 2015). This viewpoint lends itself to the scientific method of enquiry, in that the elements that can be subjected to a quantitative analysis and investigation. Therefore, by its nature, the scientific method is reductionist, as identified by Creswell (2013) and Williamson (2002).

Subjectivism considers that it is the perceptions and actions of the social actors that create the social entity itself, and that the continuous interaction of the social actors results in the constant state of change in the social phenomena (Bryman, 2008) (Babbie, 2013). A social constructionist viewpoint helps with the understanding of the details of what is happening as a result of these interactions.

The research question to be addressed involves the analysis of university education in the BSE field, and as such is interpreted through the researcher's experiences in their own work environment and the culture of that organisation, thus the observations made will inevitably be dependent upon the human perceptions of the researcher.

3.3.2 Epistemology

Epistemology is concerned with the theory of knowledge with regard to its methods, validity and scope, and the distinction between justified belief and opinion. It describes how research philosophy and the theory of knowledge must be considered (Bryman, 2008) and, leading on from this, what constitutes justifiable knowledge as opposed to groundless opinion (Saunders, Lewis, & Thornhill, 2015).

Positivism as a philosophical position in research maintains that only "factual" knowledge gained through observation and measurement is reliable, and adopts a scientific stance to collect data about observable realities. Positivism searches for correlations, trends and causal relationships in data to imply generalisations and derive theories and laws (Gill & Johnson, 2010). In positivist studies the role of the researcher is restricted to the collection and interpretation of data using objective approaches, and the research findings will be strictly quantifiable.

Realism as a research philosophy also relates to scientific enquiry, but explores the subjectivity/objectivity of the human mind. As a branch of epistemology, this philosophy is based on the assumption of a scientific approach to the development of knowledge. Realism can be divided into two groups: direct and critical.

Direct realism (sometimes also termed common sense realism) portrays the world through human senses in a purely objective way, and can perhaps best be described as "what you see is what you get". It can be argued that this is often the best way to collect data (Saunders, Lewis, & Thornhill, 2015). Critical realism (also termed transcendental realism), on the other hand, argues that this is an oversimplification of the realist philosophy, and, because of the subjective nature of the human condition, the act of observation itself affects the patterns and events being observed (Bhaskar, 2008). There is seemingly no real agreement on this point and some observers argue that critical realism can offer mistaken and deceptive perceptions, which may not portray the real world (Novikov & Novikov, 2013).

Interpretivism attempts to integrate human interest into a study. Accordingly, "interpretive researchers assume that access to reality (given or socially constructed) is only through social construction such as language, consciousness, shared meanings, and instruments" (Myers, 2008). Interpretivism is "associated with the philosophical position of idealism, and is used to group together diverse approaches, including social constructivism, phenomenology and hermeneutics; approaches that reject the objectivist view that meaning resides within the world independently of consciousness" (Collins H. , 2010). In more straightforward terms, it could be considered that the interpretivist approach leads the researcher as a social actor to appreciate differences between people and their interpretations of data and events (Saunders, Lewis, & Thornhill, 2015).

Interpretivism is recognised as originating from two intellectual traditions, namely "phenomenology" and "symbolic interactionism". Phenomenology is the science that studies the relationship between facts (phenomena) and how facts are interpreted within the human consciousness and psyche. Put another way, phenomenology is the part of the positivist philosophy that analyses and studies phenomena in the context of human consciousness, as opposed to the precision of objective measurement procedures (Easterby-Smith, Thorpe, Jackson, & Lowe, 2011) (Collis & Hussey, 2009). Symbolic interactionism offers a slightly different, though not contradictory view, in that it recognises people as being in a continual process of interpreting the actions of others with whom they interact, and this interpretation leads to an adjustment of their meanings and actions (Saunders, Lewis, & Thornhill, 2015).

3.3.3 Pragmatism

Tashakkori and Teddlie (1998) argue that philosophical choices adopted in any research need not necessarily be seen as a mutually exclusive choice between epistemological and ontological positions, and advocate that the philosophical standpoint may be seen as a continuum embracing both. Pragmatism argues that the most important determinant of the research philosophy is the research question, and that it is possible to work with both philosophical standpoints (Easterby-Smith, Thorpe, Jackson, & Lowe, 2011). A pragmatic research philosophy suggests that there are singular and multiple realities that are open to empirical inquiry, positioning itself toward solving practical problems in the ‘‘real world’’ (Creswell, Hanson, Clark-Plano, & Morales, 2007) (Dewey, 1925) (Rorty, 1999). Pragmatism therefore offers a middle ground, enabling the researcher to use empirical methods without superfluous and unnecessary qualification (Cameron & Price, 2009). Tashakkori and Teddlie (1998) further suggest, that in exercising a pragmatic approach, researchers should study what is of worth to them in ways they deem apposite, and use the results in ways that can bring about positive consequences within a suitably considered value system.

3.3.4 Philosophical stance adopted by this research

This research requires a knowledge and understanding of education, qualification and registration systems for engineers in the UK and overseas, in order to synthesise a new model that overcomes identified shortcomings and weaknesses. The researcher started from a position of working within the UK HE system, and therefore had a good deal of (potentially incomplete or incorrect) knowledge about the subject and already held (possibly biased) opinions. Therefore, the research direction needed to be guided by initial findings, and thus a pragmatic approach incorporating both positivist and interpretivist positions has been adopted.

In this work the researcher obtains knowledge from a subjective ontological perspective drawing perceptions and subsequent actions from a number of stakeholders in engineering education, what Saunders et al (2015) would term in the context of research, the “social actors”. An interpretivist epistemological position has been taken, since, as Neuman (2006) suggests, this sanctions the interpretation of motives, meanings, reasons and other subjective experiences which may be fully or partly dependent upon context.

3.4 Research approach

Determination of the research approach provides direction for the research design, the method of enquiry, the method of data collection and the way in which data will be analysed. The relationships between theory, method and empirical phenomena must be carefully considered when designing the research approach (Saunders, Lewis, & Thornhill, 2015).

There are three principal research approaches appropriate to this work, each with its own specific links to theory; deduction, induction and abduction (Dubois & Gibbert, 2010).

3.4.1 Deductive research

The deductive approach starts with a theory, often related to a hypothesis, which is then tested through empirical observation. Ketokivi & Mantere (2010) offer the view that deduction is "a form of reasoning where a conclusion is logically derived from a set of premises" and thus any conclusion cannot contain new knowledge. Deductive studies often involve testing theoretical propositions through empirical investigation and this can lead to the testing of prior hypotheses or theories using quantitative data that incorporates standardised measures and statistical techniques (Saunders, Lewis, & Thornhill, 2015).

3.4.2 Inductive research

In contrast, inductive reasoning attempts to identify themes and patterns from analysis of data to formulate new theories and create new conceptual frameworks (Saunders, Lewis, & Thornhill, 2015). Induction thus formulates concepts and develops theories to explain empirical observations rather than setting out to test theories or hypotheses (Spens & Kovács, 2006). Blaikie (2009) argues that in the social sciences, inductive research techniques can establish generalisations and infer theories by seeking patterns and correlations in observed or measured characteristics of individuals and social phenomenon. Participants contributing to an inductive study may therefore be selected by the researcher based on their appropriateness to the research question (Philip, 1998).

3.4.3 Abductive research

The abductive approach is similar in some ways to deductive research in that it also tests a theory by empirical observation. Blaikie (2009) explains that the difference with the abductive research is that it aims to understand rather than to explain, and provides reasons rather than causes; put more simply, induction seeks answers to "what" questions, while an abductive research strategy aims to also answer "why" questions. Furthermore, an abductive approach could be considered, in effect, to combine both deductive and inductive approaches (Saunders, Lewis, & Thornhill, 2015), though abduction develops a theoretical understanding informed more by context, meanings, interpretations and perspectives (Bryman, 2012). There is, however, a valid argument, related by Timmermans & Tavory (2012), that the similarity between abductive and deductive approaches can sometimes lead to misinterpretation and confusion. In response, Timmermans & Tavory (2012) suggest that abductive researchers must provide rigorous and unambiguous explanations of their research processes to ensure the level of reliability that could enable other researchers to replicate the research and its findings.

Densombe (2008) takes a pragmatic view of which approach to implement, suggesting that the choice of research approach may actually be selected to complement the nature of the research project itself. He argues that the method of investigation need not be led entirely by the research philosophy employed, since this could ultimately prove to be over-restrictive. Saunders et al (2015) concur, and consider that it is indeed possible, indeed preferable, to combine inductive, deductive and abductive approaches as appropriate, depending upon the nature of the research question.

3.4.4 Research approach adopted in this project

There is a great deal of literature dealing with comparative education in the international sphere, and a good quantity dealing with engineering education, but there is very little referencing the BSE specialist area. The research approach adopted in this study is therefore an abductive approach, since this is best suited for research topics with a shortage of literature in actual context. The research commences with an inductive approach of the literature, extracting the relevant information and knowledge to inform the themes addressed in the exploratory interview questions. A deductive approach was then taken in the thematic design of the questionnaire survey and in-depth interview questions, and this in turn allows interaction between empirical observation and theory, and, as Van Maanen et al (2007) would advocate, this encourages the generation of unexpected new ideas and revelations.

Abduction can be aligned with both subjectivism and Interpretivism and as such is an appropriate research approach to be adopted by this study (Blaikie, 2010). The themes identified in the exploratory semi-structured interviews and questionnaire survey then inform the detail in the questions for the second round of in-depth semi-structured interviews. The use of interviews in tandem with a questionnaire are consistent with an abductive approach informed by context, people and their worldview in terms of language, meanings and perspective, and quantitative and qualitative data gleaned from these approaches enable this work to build a theoretical understanding of the structure and detail of a new education and training model. Finally, the model is validated via a final round of semi-structured interviews, which were developed using inductive and deductive logic.

3.5 Qualitative, quantitative and mixed research methods

The research methods selected must enable the research questions to be addressed with appropriate data collection techniques. Knight & Cross (2012) consider that in this type of research work, the methodological choice is normally whether to employ qualitative or quantitative methods, or a well-crafted mixture of both.

3.5.1 Qualitative research methods

Qualitative research methods are seen as a tool for social research where phenomena are studied that can best be interpreted by participants' perceptions, rather than using statistics or other mathematical tools (Bryman & Bell, 2007). Such methods constitute a form of social inquiry that focusses on the way individuals or groups perceive and make sense of subjective experiences, seeking to understand people's attitudes, behaviour and experiences arising from their experiences (Dawson, 2009). Qualitative research seeks to develop theories, inferences and implications from the study of data obtained from participants' social reality.

Snape and Spencer (2003) identify a series of distinctive characteristics of qualitative research, many of which are very relevant to the context of this work. These are summarised and paraphrased below:

- The research may aim to understand, interpret and contextualise the social environment of research participants, studying their circumstances, experiences, perspectives and so on;
- The research may be based upon small samples that are selected on the basis of salient criteria;
- The data collection process may involve a close and interactive relationship between the researcher and the research participants, and this relationship may be developmental to allow emergent issues to be explored;
- The data collected may be very detailed, information rich and extensive;
- The process of data analysis should be open to emerging concepts and ideas, and this may produce detailed classifications, identify patterns, or develop typologies and explanations;
- Research outputs and conclusions may focus on the interpretation of opinion related data and inferences from these data.

Qualitative research can often be linked with an interpretive philosophy since it attempts to infer overall patterns about the phenomena being studied by interpreting participants' observations, opinions and views. Saunders et al (2015) suggest, however, that when utilised as part of a mixed methods approach, it can also be associated with the realist and pragmatist philosophies. Qualitative research involves the observation and interpretation of circumstances, happenings, interactions and behaviours, and allows people to describe their own experiences, attitudes, beliefs, thoughts and reflections (Silverman, 2009). Since qualitative enquiry is not based on numeric data to formulate conclusions, it is often described in relation to inductive logic through building a rich theoretical description of the meaning of collected and analysed data (Saunders, Lewis, & Thornhill, 2015).

The commonly used strategies and techniques for decoding, translating and drawing inferences from observed occurrences in qualitative research include grounded theory, ethnography, action research and case study (Van Maanen, Sørensen, & Mitchell, 2007).

- Grounded theory methodology was developed in 1967 by Glaser and Straus, and is recognised today as a technique to systematically derive theories of human behaviour from empirical data to make sense of everyday experiences in specific situations (Glaser & Strauss, 1967) (Charmaz, 2006). The process involves several steps of data collection in tandem with sequential data analysis, and coding of the data to reflect emerging issues. Each stage of the process is reflected upon to guide the next stage until the final theory is eventually grounded (Jones & Alony, 2011). As this theory has been used and developed over a period of time, its originators have adopted different positions in relation to its application: Glaser (1992) suggests that grounded theory should be originated with a completely empty mind to eliminate unconscious bias, while Strauss & Corbin (1997) contend that it is better to start with a general understanding of the area under research in order to drive the emergence of the theory.

- Ethnographic study is described by Creswell (2013) as a method which aims to describe and interpret shared patterns of behaviour, language and beliefs of a group of interacting individuals on the basis that what people believe, understand and act upon cannot be detached from context. It requires the researcher to focus upon describing and interpreting the social group through first hand study so that a balance is achieved between the perspectives of those inside the social group and those outside (Saunders, Lewis, & Thornhill, 2015). This, Saunders et al (2015) argue, maintains open-mindedness and allows the interpretations of those within the study to be meaningful to those outside. Such techniques are widely utilised in the fields of IT and data management research (Davies & Nielsen, 1992).

- Action research is described by Baskerville & Wood-Harper (1996) as a participatory technique requiring close collaboration between practitioners and researchers, where the researcher operates within the field of the research and becomes a participant in the process of change. Saunders et al (2015) consider action research as an appropriate method for research projects analysing the management of change. Action research encourages collaboration between the researcher and practitioner to address real problems, allowing the researcher to gain feedback from the practitioner in order to adjust and develop the research direction and outcome. It is therefore problem focused, context-specific and forward looking and is best utilised in change intervention (Hart & Bond, 1995).

Action research is not without its weaknesses, however: Argyris and Schon (1991) argue that scientific rigour can be overlooked if there is a need to produce immediate and practical research findings in an organisation.

- A case study is a pragmatic inquiry that examines a contemporary phenomenon within its real-life context and such a study can provide a rich mix of both qualitative and quantitative data (Yin, 2003). A variety of methods can be used to obtain in-depth knowledge to explore a particular phenomenon in a normal situation (Collis & Hussey, 2009), though Creswell (2013) warns that the selection of a suitable case or cases can be a dilemma for the researcher.

The process of acquiring data in qualitative studies is usually through the method of interviews, focus groups or by open ended questionnaires. Creswell (2009) suggests that these techniques can be used to acquire rich, in-depth views and opinions in relation to the research question and usually involve fewer people than quantitative studies; however, qualitative studies normally require participants to give a greater amount of their time. Naoum (2013) considers that qualitative studies may adopt either exploratory or attitudinal strategies. An exploratory strategy is appropriate when limited knowledge is available on a subject (or the researcher wishes to gain additional dimensions to existing knowledge), whereas an attitudinal strategy lends itself to evaluating views and perceptions that already exist with respect to the subject.

When analysing qualitative data, however, the researcher must seek to provide explanations of what has been observed based on a holistic interpretation of the empirical data (Carcary, 2009). Just how competent this analysis is, argue Miles & Huberman (1994), is a measure of the strength of the qualitative method. Furthermore, the time taken to analyse qualitative data can be far longer than the time taken to analyse quantitative data, where computer programmes can be utilised to generate results in an efficient manner (Berg, 2009).

Qualitative methods have certain strengths: It can certainly be argued that qualitative studies enable researchers to acquire a more realistic impression of the world that cannot be gleaned from the numerical and statistical analysis used in quantitative research. Bogdan & Biklen (1992) argue that such methods provide a holistic view of the phenomena under investigation. Qualitative methods incorporate flexible means of carrying out data collection (including the possibility of interacting with research subjects on their own terms), subsequent data analysis, and interpretation of collected information (Kirk & Miller, 1986).

Naturally, there are also weaknesses inherent in a qualitative approach: Cassell & Symon (1994) submit that there is a real possibility of departing from the original objectives of the research in response to the changing nature of the context. There is also the possibility that the researcher's inherent unconscious personal prejudices may lead to inconsistent or incorrect interpretation of data and incorrect conclusions, and this can also lead to connections between different research phenomena being overlooked or misinterpreted (Cassell & Symon, 1994). It is also suggested that a high level of experience from the researcher I required to obtain the correct information from the respondent; the researcher may well find it difficult to deal with differences in quality and quantity of information obtained from different respondents. In addition, consistency and reliability can be questioned if the researcher employs different exploratory techniques and respondents choose to tell some stories while ignoring others (Matveev, 2002).

3.5.2 Quantitative research methods

Bryman & Bell (2007) consider that "quantitative research develops and uses mathematical models, theories and hypothesis to describe relevant natural phenomena", assuming an objective social reality in which to work. The main purpose of quantitative research is to explain the causes of phenomena being observed by comparing theory and practice, identifying discrepancies, carrying out statistical analysis, and making connections and generalisations (Crotty, 1998) (Cameron & Price, 2009). Quantitative research frequently uses established principles to determine the data that will be collected, and unlike qualitative research, a quantitative study will typically collect and analyse numerical data, being concerned with statistical or mathematical analysis, rather than words, meanings and inferences which typify qualitative studies (Cameron & Price, 2009).

The common research approaches adopted within quantitative research are typically experimental and survey approaches, adopting questionnaires or structured interviews to quantify the collected data (Saunders, Lewis, & Thornhill, 2015). These approaches use standardised measures that allow for the varying perspectives and experiences of people to be fitted into a limited number of predetermined response categories, to which numbers may be assigned (Ghauri & Grønhaug, 2005). Quantitative studies are tightly structured, emphasising the precision of the measurement procedure (Easterby-Smith, Thorpe, Jackson, & Lowe, 2011).

Experimental methods are commonly used in the sciences and consist of a collection of research designs that use manipulation and controlled testing to understand casual processes. Such a strategy tends to use predictive hypotheses as opposed to open research questions. As the research question and objectives have been said to inform the strategy, the researcher must consider the nature of the research question in its selection (Saunders, Lewis, & Thornhill, 2015).

Use of surveys is usually associated with a deductive research approach and this can often be a good fit for business, management and educational research to address a series of questions including "what", "who" and "where" (Saunders, Lewis, & Thornhill, 2015). Surveys can be associated with both qualitative and quantitative research as they collect data via structured interviews and questionnaires, normally on several cases and variables in order to establish patterns (Bryman, 2012). When an appropriate sampling method is used it is possible to draw conclusions about the whole population providing the sample collected is representative of that population.

Quantitative research has certain well documented strengths: It is possible in quantitative studies to state the research problem in very specific and exact terms, and to clearly and precisely specify both the independent and the dependent variables under investigation (Frankfort-Nachmias & Nachmias, 1992). Kealey and Protheroe (1996) further consider that subjectivity of judgment can be minimised or even eliminated in quantitative studies. It is also claimed that high levels of data reliability will result from the tight control of observations, experiments, surveys and so on, and by resolutely pursuing the original research goals, testing the hypothesis, and determining the issues of causality, more objective conclusions are likely to emerge (Balsley, 1970).

Matveev (2002) catalogues the various weaknesses of the quantitative survey approach: Such methods may be considered restrictive, in that they do not allow the research project to continuously evolve in the same way that qualitative methods do. In addition, there is an inherent inability to control the environment where respondents provide answers to survey questions, particularly where the researcher fails to provide sufficient information on the context of the research question. Such restrictions, it is argued, can lead to limited and inconsistent outcomes (Matveev, 2002).

3.5.3 Mixed research methods

The central premise of a mixed methodology is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone (Creswell, Hanson, Clark-Plano, & Morales, 2007). As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative data in a single study or series of studies. Using mixed methods in a research project requires the philosophical stance and methods of inquiry to be first established and stated.

As both quantitative and qualitative methodologies have positive and negative attributes, there is often a justification for combining these in order to neutralise or reduce any potential bias (Creswell, Hanson, Clark-Plano, & Morales, 2007). Blaikie (2010) advises, however, that since mixed methods use more than one data collection method and analytical procedure, these need to be allied carefully with ontological positions appropriate to each. Two philosophical positions can lead to mixed methods research designs. For example, where a realist ontological position and interpretivist epistemology are adopted, researchers may use quantitative analysis of officially published data followed by qualitative research methods to explore perceptions (Tashakkori & Teddlie, 1998). A mixed methods research design may adopt either a deductive or inductive approach or a combination of the two, since “quantitative or qualitative research may be used to test a theoretical proposition, followed by further quantitative or qualitative research to develop a richer theoretical perspective" (Saunders, Lewis, & Thornhill, 2015, p. 164).

Doyle et al (2009) suggest that when designing a mixed method data collection and analysis project, the researcher must make three primary decisions: whether both the methods are given equal priority, whether to conduct the qualitative and quantitative stages concurrently or sequentially, and where in the work will the qualitative and quantitative methods be mixed.

Creswell (2009) suggests that in a properly designed mixed methodology, qualitative and quantitative data collection and analysis may be conducted sequentially or concurrently. Sequential mixed methods involve more than one phase of data collection and analysis, utilising the data from one method to inform the findings of the other. Where qualitative data informs the quantitative data it is termed "sequential exploratory design" and where quantitative data informs the qualitative data it is termed "sequential explanatory design". Multiple phases of data collection can also be included in sequential mixed methods, known as multiphase design, whereas, concurrent mixed method research, adopts a single phase of both quantitative and qualitative data collection and analysis (Creswell J. W., 2009).

In mixed methods research, quantitative and qualitative data collection methods may be used equally or unequally (Creswell, Hanson, Clark-Plano, & Morales, 2007). Morse (2010) asserts that a mixed method design should involve a primary method be it either quantitative or qualitative, and one or more supplementary components of either quantitative or qualitative research that provide insights and examinations for the primary component of the research data, such as interviews. It must be noted however, that the participants of both the primary and the core may or may not be the same, but must be from the same population (Morse, 2010). Where one methodology supports the other it is referred to as "embedded mixed methods research" and where one methodology is embedded within the other in a single data collection then it is known as "concurrent embedded design" (Creswell, Hanson, Clark-Plano, & Morales, 2007).

Johnson and Onwuegbuzie (2004) identified a series of strengths and weaknesses of mixed methods, and these are summarise below:

Strengths

- Words, illustrations, and narrative can be used to add meaning to numerical, statistical or graphical data;
- Conversely statistical clarification can be used to add precision to words, pictures, and narrative;
- Mixed methods can make best use of the strengths of both quantitative and qualitative methods;
- The researcher can generate and test a grounded theory;

- Results can be used to develop and inform the purpose and design of subsequent stages in the research, and thus the research can answer a broader range of research questions;
- Convergence and corroboration of findings using alternate methods can provide stronger evidence for conclusions;
- Insights and understanding can be included that may be overlooked when only a single method is used;
- Qualitative and quantitative research used together produce more complete knowledge necessary to inform theory and practice.

Weaknesses

- It can be difficult for a single researcher to carry out both qualitative and quantitative research, especially if two or more approaches are expected to be used concurrently;
- The researcher must learn to use multiple methods and approaches and understand how to mix them appropriately;
- Methodological purists contend that one should always work within either a qualitative or a quantitative paradigm;
- Mixed methods use may be more expensive and time consuming;
- Some of the details of mixed research remain to be worked out fully by research methodologists (e.g., problems of paradigm mixing, how to qualitatively analyse quantitative data, how to interpret conflicting results) (Johnson & Onwuegbuzie, 2004).

3.6 Research ethics

It cannot be disputed that research should be conducted in an ethical and responsible manner. As minimum requirements, research data should not be falsified or plagiarised, and research participants should be guaranteed adequate protection and confidentiality. Since this research project involves eliciting opinions and views from human subjects, it is particularly important that the protection of research participants is properly addressed alongside all other ethical considerations.

There are several texts which discuss and define research ethics, and analyse what constitutes acceptable research conduct and practice. The disciplines of social science, such as philosophy, theology, psychology, sociology and so on, where standards of human conduct are routinely scrutinised, provide significant insight and a good quantity of such literature on research ethics, see for example Creswell et al (2007), Niglas (2010) and Saunders et al (2015).

Two contemporary sources, pointing to similar methodologies to those employed here, have been selected to contribute to an ethical framework for this particular project.

Nichols-Casebolt (2012) points to seven areas which are essential to responsible research conduct, and these can be summarised thus:

- That there is a clear and prescient understanding of what constitutes research misconduct,
- That research mentors (“supervisors” to UK readers) foster a climate promoting ethical conduct,
- That it is recognised that conflicts of interest or commitment can bias professional judgement,
- That the necessity for interdisciplinary collaboration is recognised,
- That human research subjects should be appropriately protected,
- That best practices in data storage and management are applied,
- That the dissemination and publication of research findings is handled reliably and with integrity.

The process of what constitutes satisfactory and acceptable research conduct can be described in various ways. Shamoo and Resnik (2009) advance a useful definition (that is echoed across much of the literature) that ethical research leads to methods of deciding how best to act when critically analysing complex problems and issues. Behavioural norms become evident in various disciplines and researchers must establish and conform to the norms within their own particular research community in order to elicit trust from peers and, in the wider arena, to ensure public accountability. The views of Shamoo and Resnik (2009), relating to what they term “ethical norms” can be summarised in the list below, that ethical practice should seek:

- To promote the aims of the research, such as knowledge, truth and the avoidance of error,
- To promote values that are essential to collaborative work,
- To ensure that researchers can be held accountable,
- To help build (public) support for research,
- To promote a variety of positive moral and social values.

It is evident that different professional associations, government agencies, universities, academic societies and individual research institutions adopt specific codes, rules, and policies relating to research ethics. Although this particular project is of interest to both the Engineering and Construction communities, it is primarily a piece of research in the Educational field, and methodological approaches relevant to Educational research have been used. Therefore the ethical guidance informing this work overall is the British Educational Research Association publication, "Ethical Guidelines for Educational Research" (BERA, 2011). The aim of these guidelines is "to enable educational researchers to assess all aspects of the process of conducting educational research within any given context and to reach an ethically acceptable position in which their actions are considered justifiable and sound", and advises on best practice for ensuring protection of human subjects (BERA, 2011). Furthermore, this research project gained ethical approval from the Research Committee of Liverpool John Moores University in March 2012.

The main participants in this research are the various stakeholders in BSE education, such as EC and PEI staff, members of relevant PEIs, academic staff in universities, representatives of employers, and finally, a number of BSE students. The research was carried out with due regard to anonymity and confidentiality of the subjects, with no account taken of age, sex, race, religion, political beliefs or any other societal characteristic. In all cases, standard information, approved in advance by the LJMU Research Committee, was provided to participants. This informed subjects explicitly that their participation was voluntary, and made clear to the subjects why they had been selected to participate, and why their input might be useful given the nature of the research question. It was made clear that all personal data would be handled in accordance with the Data Protection Act, 1998, and the way in which the subjects' responses and information would be used was clarified. Participants were also advised that they had the option to withdraw from the research at any time for any reason if they so wished. Due attention was paid to the time required for participation in the research, and every attempt was made to minimise the impact of the research on participants' normal workloads. The standard information given to all participants further confirmed that confidentiality and anonymity would be assured in the reporting and discussions of findings.

Chapter 4 – Data Analysis

4.1 Sampling

When using quantitative, qualitative or mixed methods with human participants, appropriate sampling techniques must be established. The population from which a sample can be drawn would include every person who holds any stake at all in the research question: it is of course unfeasible in most cases to gather data from such an extensive population, therefore representative sampling is necessary. Becker (1998) considers that the sample(s) to be studied should be shown to represent the full population in a way that is meaningful and justifiable. Creswell (2013) also advises that the decisions on sampling methods, sample sizes, and choices about who or what should be sampled are crucial to the success of any research study.

In any research, the sample size must be sufficient to satisfy the requirements of the method adopted to analyse the data. It follows of course that, in simple terms, the larger the sample size, the more likely the data will be to a normal distribution, and thus the findings may be considered more robust. Early literature on sample size appears to concentrate on absolute numbers to ensure that sufficient data are generated to demonstrate a normal distribution. Researchers are advised that absolute minimum sample sizes should be somewhere between 200 and 500 [see for example Guilford (1954), Comrey (1978) and Browne (1968)].

More recent literature suggests, however, that the imposition of absolute sample sizes is largely misconceived: MacCallum et al (1999) suggest that there are no absolute thresholds, since an acceptable minimum sample size must be a function of several inter-related parameters. A framework for establishing sample size, taking account of the relative influences of such elements as the number of factors being investigated, the number of variables per factor, the level of commonality between the variables, and the loadings applied to each variable, was developed by MacCallum et al (1999) to assist with this.

There are a large number of established sampling techniques, and the disciplines of social and behavioural sciences, where human subjects are almost always necessary in research projects, consider the various techniques to sit broadly in one of two groups: probability and non-probability (Saunders, Lewis, & Thornhill, 2015).

Since mixed research methods are used in this project, consequently a mixed methods sampling strategy was employed. This involves the selection of participants using both probability and non-probability sampling techniques: probability sampling to increase external validity, and purposive sampling strategies to increase transferability, as suggested by Collins et al (2007).

4.1.1 Non-probability sampling

Non-probability sampling, also known as purposive sampling, eschews random selection of participants in favour of deliberate selection, and is therefore more appropriate for qualitative studies (Teddlie & Yu, 2007). In purposive sampling, particular individuals or organisations may be intentionally selected specifically for the important information they can provide in relation to the research question (Maxwell, 1997) (Bryman, 2012). Mason (2002) describes the notion of a "sampling frame" being a resource from which a sample may be selected and considers that in purposive sampling, such frames are typically informal, based as they must be upon the expert judgment of the researcher or another available resource that the researcher identifies.

The selection of participants in the three rounds of semi-structured interviews adopted such a purposive strategy, since the contributors needed to be highly knowledgeable about some quite discrete and distinct subject matter where the majority of engineers and educationalists would likely be quite ignorant. Although the number of interviews carried out is relatively small in a global or even a UK context, it must be noted that there are only a very limited number of people who would usefully hold opinion and be able to volunteer sufficient knowledge on the research question. It was therefore considered that a sufficient number of interviews with a sufficiently wide variation of interviewees was carried out. In the first cases respondents of the four exploratory interviews were professional contacts of the researcher who were known to have substantial professional experience working in the area under investigation, and would therefore be sufficiently knowledgeable to contribute meaningfully. The subsequent interviewees were then either other professional contacts of the researcher or were recommended to the researcher by interviewees who had already agreed to participate. The professional backgrounds of the interviewees was varied (as described in Section 3.2.5) to ensure that the wide ranging research objectives were addressed as much as possible, whilst courting a correspondingly wide range of opinion and knowledge.

4.1.2 Probability sampling

Tashakkori and Teddlie (2003) consider that probability sampling techniques are most suited to quantitative research studies since they involve the randomised selection of a relatively large number of individuals from a population, or from specific strata of a population. In probability sampling, every member of a population has an equal chance of being selected as a subject for the research, and this guarantees that the selection process is random and without bias. Because of the size of samples such techniques are particularly appropriate for the collection of quantitative data.

A probability sampling technique was used for the circulation of the questionnaire survey in this research. Since the required respondents to the questionnaire needed to be members of PEI staff with knowledge and experience of the UK-SPEC, registration and professional membership of engineers, AHEP 3 and academic course accreditation, the population in this respect was limited and a small, though a highly representative, number of responses was required. Responses were therefore sought from PEI employees working in roles relating to membership, engineer registration and course accreditation, which would mean that they have sufficient knowledge of the issues surrounding the research question, which would qualify them to hold considered and valid opinions. The questionnaire was therefore aimed at a population consisting of around 170 individuals, as detailed below:

- Four large PEIs with 10 – 15 qualified employees = approx. 50
- 11 medium sized PEIs with 5 – 10 qualified employees = approx. 90
- 20 small PEIs with 1 – 2 qualified employees = approx. 30

A total of 82 valid responses were received which represents a 48.2% response rate. Nulty (2008) suggests that online surveys typically attract response rates of between 33.3% and 39.6%, while Salvidar (2012) reflects that a 30% response rate for online surveys is average, and 50% may be considered as good.

4.1.3 Pilot sampling

It is well established practice, before embarking fully upon data collection, for the researcher to undertake non-probability pilot samples, involving participants who are readily and easily available (Stone, 1993) (Fellows & Liu, 2015) (Saunders, Lewis, & Thornhill, 2015). The questionnaire survey in this research was piloted appropriately as described in Section 3.2.3, and, since a small round of exploratory interviews, as described in Section 3.2.5, was carried out at an early stage in the project, the semi-structured interview process was, in effect, also piloted.

4.2 Data types

To classify quantitative data, Saunders et al (2015) propose the use of four measurement scales to categorise different types of variable: nominal, ordinal, interval and ratio.

Nominal data are purely descriptive and therefore are normally classified into categories or themes according to the characteristics that describe the variable. The identification and analysis of themes was the main approach taken with data obtained from the semi-structured interviews.

Saunders et al (2015) suggest that for ordinal, interval and ratio variables, numerical values should be ascribed so that the data can be ordered and arranged logically, and analysis can be carried out using statistical methods.

Ordinal scales are typically used to measure non numeric concepts such as satisfaction or agreement and identify the data in rank order. Ordinal data is the more precise form of categorical data in that the relative position of each case within the data set is known, for example using the Likert scale previously discussed, possible responses may for example be “strongly agree”, “generally agree”, “neither agree nor disagree”, “generally disagree” and “strongly disagree”. Each of these responses may be ascribed a numerical value to enable statistical or mathematical analysis.

Data which have numerical values that can be measured or counted is termed numerical data (Saunders, Lewis, & Thornhill, 2015), and such data can be analysed using either interval or ratio methods. Interval measurement utilises the fixed interval between any two data values for a particular variable, for example 0 – 5 years, 5 – 10 years, 10 – 15 years, whereas ratio data allows the researcher to calculate the relative difference between any two data values for a particular variable.

The questionnaire survey used in this research, described in Section 3.2.3 was designed to collate individual perceptions of PEI staff members based on their personal experience and knowledge, using Likert scales and single choice selection questions to elicit quantitative data, and free text boxes to elicit qualitative data where this could be useful. The data types to be used for analysis are there nominal, ordinal and interval. On questions using the Likert scale, respondents were asked to select from a choice of 5 attitudinal positions and each was allocated a numerical score:

- Strongly disagree = 1
- Generally disagree = 2
- Neither agree nor disagree = 3
- Generally agree = 4
- Strongly agree = 5

Other variables were measured by asking the respondents to answer specific questions that could then be later measured by applying a score against the response. For example, question 7 asks “How often do you, representing your PEI, interact or correspond with any of the other Engineering Council licenced PEIs?” and provides the options, “Very regularly/daily”, “Quite regularly/weekly”, “Quite rarely/monthly”, “Very rarely/annually” and “Never”. These can be ascribed numerical values to enable quantitative analysis.

4.3 Analysis of exploratory semi-structured interviews

The exploratory semi-structured interviews were undertaken with a small number of respondents as described in Section 3.2.4. To recap: the participants were a senior member of CIBSE staff, a senior member of IET staff, and two BSE industry experts and practitioners, both Chartered Engineers, one a CIBSE member, the other a member of the CIPHE. All participants at the exploratory stage were known to the researcher in a professional capacity and were known to have substantial experience and knowledge that would enable them to contribute meaningfully and insightfully to the research topic. The questions around which the semi-structured interviews were based are reproduced in Appendix 5.

The purpose of these interviews was to investigate, in the context of the literature, the premise of the research question and establish main themes for further investigation. The data were therefore analysed thematically in respect of the first two specific research objectives:

Objective 1 *– Examine the development of the EC and PEIs and critically review their influence on BSE academic programmes and qualifications.*

Objective 2 *– Investigate the introduction of the UK-SPEC and critically review the EC's approach for making judgements about the accreditation of academic programmes and registration of engineers.*

Several themes emerged for further exploration and these are summarised in the following narrative:

4.3.1 Relative sizes and influence of the PEIs

There is self-evidently a huge disparity in sizes of the PEIs according to a raw count of members and according to the number of members who are EC registrants. The two methods of classification do not necessarily correlate because for some PEI's the licencing of engineers is not their only, or indeed their main business (as discussed in Section 2.4.6).

It was suggested by all four interviewees that the early hypotheses of this work are likely correct: that the smaller PEIs do not indeed wield equal influence within the EC and were also probably not meaningfully involved in the drafting of the UK-SPEC (and the PEC statements therein) leading up to its publication. Whether this actually constitutes a problem in and of itself, and in the context of BSE education, training and registration, is an issue explored later in the work. It was believed, however, that the CIBSE, despite being a medium-sized PEI (according to both methods of classification) was very much involved in drafting the UK-SPEC, though it did not take a leading role. The CIPHE, as a relatively new PEI (it evolved from the

Institute of Plumbing which was formerly a craft and technician organisation, gaining its Royal Charter as recently as 2008), appears not to have been fully involved.

The interviewees did not see that objectively there was necessarily a problem due to the relative sizes and respective influence of the PEIs this as there are regular updates and revisions to the UK-SPEC in which all PEIs are invited to participate. It was, however, acknowledged that there is a general perception that the larger and more influential PEIs have very much designed a system that is a better fit for some branches of engineering than others.

4.3.2 Approaches to engineer registration

All interviewees agreed that there is a general perception in the engineering world of some inconsistent approaches to engineer registration across the various PEIs. All confirmed that they believed the EC is aware of this as an issue and does its best to mitigate and harmonise the approaches found in the different PEIs.

Many of the PEIs (particularly the smaller institutions with more finite resources) are, in addition to their EC licence, also licenced by other regulating bodies to register non-engineering professionals, for example Chartered Environmentalists and Chartered Physicists, and the registration processes for these professions are dissimilar in many respects to EC systems. In addition, each PEI, often for historical reasons, has its own membership applications system, and since membership and professional registration applications are often interdependent processes, these confuse the issue further.

The interviewees cited various examples (some of which were historical and anecdotal in nature) of engineers seeking CEng registration through certain smaller PEIs because their systems are perceived as less rigorous than the larger institutions.

All the interviewees believed that among the PEIs, the CIBSE has one of the most rigorous and consistent registration systems, and CIBSE processes and procedures are often cited as exemplars. This is important in the development of the proposed education and training model since it indicates that a degree of confidence can be ascribed to current CIBSE methods and practices.

4.3.3 Lack of parity between IEng and CEng registration

All interviewees pointed out that the hierarchical nature of the engineering profession, apparently unwittingly propogated by the EC, is detrimental in recognising the very real contributions of Engineering Technologists (Incorporated Engineers), those professionals whose role is to innovatively apply established technologies rather than contributing to research into new engineering knowledge. Although the EC constantly assures that CEng and IEng registration should have equivalent status, CEng registration is most usually perceived as a “gold standard”, while IEng registrants tend to be somewhat marginalised and career advancement often depends upon engineers seeking Chartered status. As reported in Section 2.4.2 there are six times as many CEng registrants as there are IEng registered engineers and all respondents agreed that this is not surprising given the way that the grading system is arranged and the attitudes and beliefs resulting from this.

There are many examples across the engineering disciplines where engineers whose skills and job roles are really commensurate with IEng registration but feel that they must aim for CEng status. For example, it is often difficult for BSEs to demonstrate in their daily work that they “seek to apply emerging technology” and “conduct appropriate research” to “undertake design and development of engineering solutions” (see CEng requirements in Appendix 1) when often they are pressured by commercial constraints to utilise established technologies and engineering solutions.

Two of the interviewees considered that the issue here is that many CEng registrants (and those seeking registration) should probably be IEng registrants where the use of existing technologies is expected, but the hierarchical nature of the engineering professions means that IEng registrants are often regarded as being less competent than Chartered Engineers.

This subject proved to be quite a point of discussion among all respondents and there were some interesting opinions given. It is, however, not the purpose of this work to challenge structures and procedures that are so well embedded, this work seeks to synthesise an education and training model for BSE that can work under present systems and provide UK graduates with international opportunities.

4.3.4 Approaches to course accreditation

There is a general perception in the engineering and academic communities of an inconsistency of approach to course accreditation across the PEIs. The premise of the course accreditation system is that the EC’s AHEP 3 publication provides a well-structured and comprehensive framework that universities may interpret when developing courses (see Section 2.7), and PEIs, when accrediting courses use the same documentation as a reference point. The interviewees felt without exception that the imposition and monitoring of output standards from educational programmes are essential to success and generally considered the output based philosophy to be the correct one.

Many of the smaller PEIs are not equipped to accredit courses independently, however, and so are members of consortia such as the JBM (as described in Section 2.7.1), while in other branches of engineering course accreditation is either not necessary or the larger PEIs carry out the accreditation. The larger PEIs such as the IMechE, IET and so on accredit a great many courses and so have developed their own systems and procedures complementing the guidance given in AHEP 3. The CIBSE has also done this and respondents held favourable views about CIBSE's systems and procedures and all generally agreed that the CIBSE is widely regarded in the engineering community as a proactive and campaigning institution.

There are, however, certain differences in approach between the various PEIs that are sometimes inconsistent with AHEP 3, and sometimes requirements are imposed upon universities which are more stringent than necessary. Again, it was generally believed by the interviewees that the CIBSE is something of a role model in this respect as it tends to take a pragmatic view and will interpret guidance in ways that are helpful to universities, rather than stolidly adhering to guidelines.

4.3.5 Nature of the PECs

The general consensus among the interviewees about the PEC statements published in the UK-SPEC was that these are meticulous and attempt genuinely, through their very generic yet wide-ranging nature, to represent every engineering discipline. All agreed that the output standards approach is without doubt the correct strategy to make sense of a series of very complicated issues. It was, however, suggested that the PECs are so generic that in many cases that their meaning becomes muddied and assistance with interpretation is needed.

The criticisms of the PECs sit generally in the following main areas:

- It requires imagination to apply the PECs equally to every engineering discipline, and PEIs must make their own decisions on how to interpret these to demonstrate applicability to their particular discipline. Some PEIs (notably in the context of this work the IET and CIBSE) issue detailed guidance to applicants and assessors on how the PECs can be demonstrated.

- There are some occupations which are legitimately related to engineering and require detailed engineering knowledge and skills, which are not actually engineering roles. The example cited by one respondent was that engineering lecturers working in colleges and universities have historically found it very difficult to demonstrate some of the PECs, particularly those relating to the provision of "technical leadership and commercial management" (see Appendix 1) and so were often denied EC registration at Chartered and Incorporated grades. It is a requirement by most accrediting PEIs, including the CIBSE, that a significant number of staff in engineering course teams hold CEng or IEng registration so this can create a problem for academic departments.

- It is sometimes difficult for the PECs to be applied to non-Western cultures. There was less immediate knowledge about this point but it was considered that the PECs are written from a standpoint indicative of Western industrialised nations, and therefore some of the cultural points of reference may be interpreted differently overseas.

4.3.6 BSE courses and curriculum

BSE has a comparatively broad curriculum as described in Section 2.6.3, while other engineering disciplines can be much more focussed in comparison. There is thus a problem for BSE degree course providers, who must require students undertaking a full-time course to become adept in a number of specialist areas, whilst simultaneously accruing the necessary fundamental skillset of mathematics, science and engineering principles. All of the interviewees opined that students should be guided much more persuasively towards pursuing the optional sandwich work placement year during their degree course, as this provides time for knowledge to be assimilated in the learner's mind whilst providing a proper vocational context for what has been learned.

All respondents agreed that there is a definite shortage of specialist BSE courses in the UK (and this is discussed earlier in this work), such that many BSE companies cannot find sufficient numbers of BSE graduates to fill vacancies. Companies therefore often resort to employing graduates from other engineering disciplines, though while such people may be very well-versed in engineering fundamentals and theory, they are not immediately occupationally competent in BSE (not surprisingly!). Companies therefore provide such employees with focussed training in the workplace to quickly enhance their BSE specialist skillset. Many BSE companies also adopt a practice of attempting to attract school leavers or (usually more successfully) skilled crafts people into the profession and then sponsoring them through their education and training. This generally involves them attending further education college on a day-release basis alongside full-time employment, and they achieve HNC, HND or FD qualifications. Such engineers can then progress onto a BSE degree course at an advanced stage if indeed a course is available locally. Anecdotally, all interviewees agreed that engineers who progress from the crafts in this manner tend to be the most occupationally capable early in their career.

The general consensus from the interviewees was that there is not much wrong with BSE education as delivered by universities and colleges, just that there is not enough provision in either sector. All respondents were clear that work based learning must feature in BSE education, and this can either be through day release university attendance or the use of sandwich placement years (or even holiday jobs in between university semesters).

4.4 Analysis of the questionnaire survey

The questionnaire survey was targeted at appropriately qualified members of staff at the PEIs as described in Section 3.2.3. There were 82 responses from PEI staff, which represents approximately a 48% response rate.

The purpose of the questionnaire was to gather quantitative data to investigate, in the context of the literature and the exploratory semi-structured interviews, the premise of the research question and establish themes for further investigation in respect of objectives 2, 3 and 4:

Objective 2 *– Investigate the introduction of the UK-SPEC and critically review the EC's approach for making judgements about the accreditation of academic programmes and registration of engineers.*

Objective 3 *– Critically evaluate the membership details of the PEIs and critically review the EC registration grades and PEI member categories.*

Objective 4 *– Examine how BSE study programmes are developed and the process of professional accreditation in the UK.*

The common software application for analysing data such as the set generated by the questionnaire in this research is the Statistical Package for Social Sciences (SPSS).

Field (2013) suggests that there are two main methods for undertaking quantitative data analysis using statistical mathematics: parametric and non-parametric methods. Parametric analysis requires data to be of the interval type, and these data should be normally distributed; that is to say, there must normally be a large number of respondents. Parametric analysis also requires all participants to be randomly selected. If, however, data are ordinal or categorical, not necessarily normally distributed, and participants are selected by the researcher then non-parametric methods can be used (Field, 2013).

In this research the population from which the sample was selected was necessarily purposive (as previously described), which appears to indicate non-parametric methods, however, the distribution of the questionnaire within the population, since snowballing was encouraged, could have tended towards a more random sample, and this could indicate parametric methods.

4.4.1 Statistical testing for data normality

The SPSS package facilitates tests for both parametric and non-parametric data sets and it is necessary to apply the correct test so that the analysis provides an accurate picture of the perceptions and attitudes of the participants. It is therefore important to carry out statistical testing for data normality to confirm whether parametric or non-parametric testing should be carried out.

Using SPSS software, the two normality tests available are the Kolmogorov-Smirnov test and the Shapiro-Wilk test and these tests were applied to the demographic of the questionnaire respondents to establish whether a normalised sample of the population had responded. Table 10 below shows the results of the two tests, the important figures here being the significance levels in columns 4 and 6. Normalised data would show significance levels of above 0.05, so therefore it can be concluded that since both tests report a significance level of less than 0.05 against each of the variables, then the data are not normally distributed.

Table 10 Test results for data normality

	Kolmogorov-Smirnov test			**Shapiro-Wilk test**		
Variable	**Statistic**	**Degree of freedom**	**Significance level**	**Statistic**	**Degree of freedom**	**Significance level**
Size of PEI (raw member count) (small, medium or large)	.248	82	.001	.796	82	.000
Size of PEI (engineer members) (small, medium or large)	.349	82	.000	.719	82	.000
Job type (membership, accreditation or executive)	.360	82	.000	.676	82	.000
Tenure (full-time, part-time or volunteer)	.539	82	.000	.215	82	.000
Length of service (< 2 years, 2 – 5 years, 5 – 10 years, > 10 years)	.301	82	.000	.788	82	.000

In this research therefore, non-parametric methods are indicated. This is not so surprising since the participants constituted a relatively small sample and were carefully selected from a discrete population, indeed a normalised set of data was not the aim. The Spearman's rho correlation test was therefore applied to establish correlations in the data, this being the commonly utilised test for the examination of non-parametric data available in the SPSS software programme.

4.4.2 Analysis and testing of data

The demographic of the respondents is as indicated by the following bar charts and discussions.

As described in Section 2.2, for the purposes of this work, PEIs are categorised as small, medium-sized and large according to the number of members at all grades and categories:

- Small PEIs are those with fewer than 10,000 members, of which there are 20;
- Medium-sized PEIs are those with between 10,000 and 50,000 members, of which there are 11;
- Large PEIs are those with more than 50,000 members, and there are four such institutions.

See Table 1 in Section 2.2 for details of PEI sizes and respective member numbers.

The bar chart (Figure 8 below) shows that 39% of the questionnaire respondents worked for small PEIs, 35% for medium sized PEIs, and the remaining 26% worked for the larger PEIs. This demographic skews the data analysis somewhat since, for the simple reason that there are many more small and medium-sized PEIs than there are large institutions, and there is therefore an imbalance. This again indicates that non-parametric statistical testing methods should be used when examining correlations between data sets.

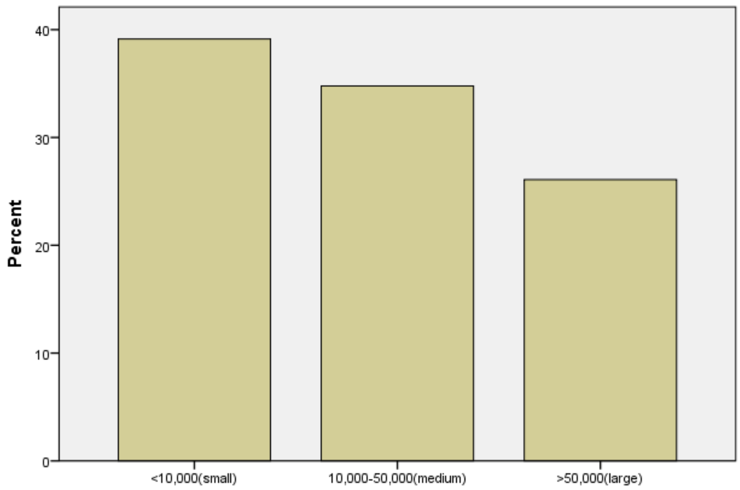

Figure 8 Demographic of questionnaire respondents – relative sizes of PEI (raw member numbers)

The possible correlation of relative sizes of institution against attitudes about the perceived consistency of engineer registration processes, and attitudes about the usefulness of the UK-SPEC and AHEP 3 publications is examined later in this section.

Also as described in Section 2.2, further demographic that is of critical to this work is the number of members belonging to each PEI who have a membership category commensurate with EC registration. For the purpose of this analysis, three categories were defined:

- Small PEIs with less than 5,000 engineer members, of which there are 25;
- Medium-sized PEIs with 5,000 – 25,000 engineer members, of which there are 7;
- Large PEIs with more than 25,000 such members, of which there are 3.

Again, these data may be seen in context in Table 1 in Section 2.2.

This is actually more indicative than the raw member count, since for some institutions [The Institute of Physics (IOP) and Chartered Institute for IT (BCS) for example], engineering is not necessarily their only, or indeed, primary business. It can be seen from the bar charts above (Figure 8) and below (Figure 9) that the PEI classifications due to member count of small, medium and large do not correlate with the number of members at grades commensurate with EC registration.

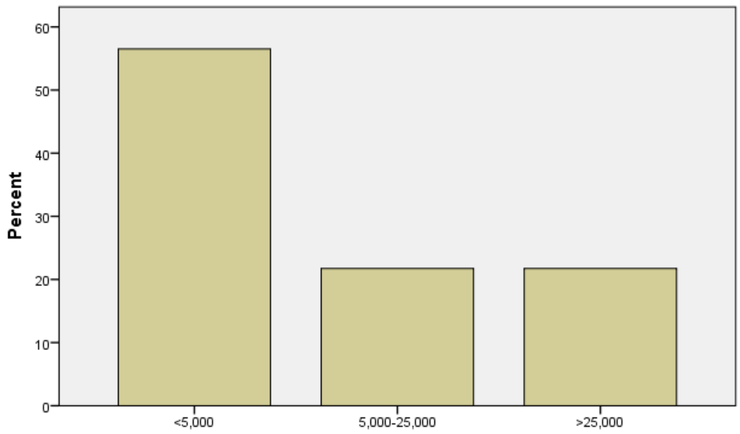

Figure 9 Demographic of questionnaire respondents – relative sizes of PEIs (EC registrants)

It should follow that in those institutions with a greater proportion of engineer members, their staff members would have a deeper understanding and appreciation of the UK-SPEC, AHEP 3 and the process of engineer registration, and their attitudes to these questions would be more positive. This possible correlation is discussed later in this section.

Of the survey respondents, the majority are employed in membership and registration roles as indicated by the bar chart below (Figure 10), although a number of personnel in executive roles also responded. There were a smaller number of respondents who were expert in course accreditation, but since not all PEIs accredit courses, and persons in executive positions would have knowledge of this subject if relevant, the demographic of respondents is again representative of the population in question.

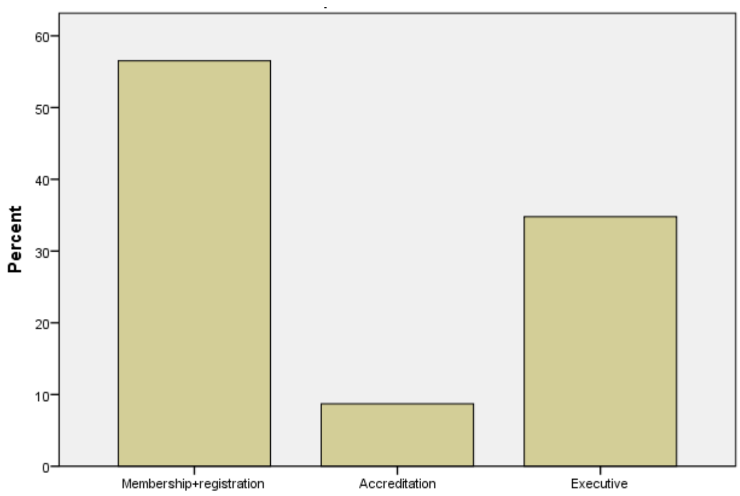

Figure 10 Demographic of questionnaire respondents – job role of respondent

The majority of questionnaire respondents were found to be full-time salaried staff rather than part-time staff, and no volunteer staff members responded, as shown in the bar chart below (Figure 11). Notwithstanding the nature of the smaller PEIs, this is indicative of the target population, since membership officers and executive officers tend to be full-time roles.

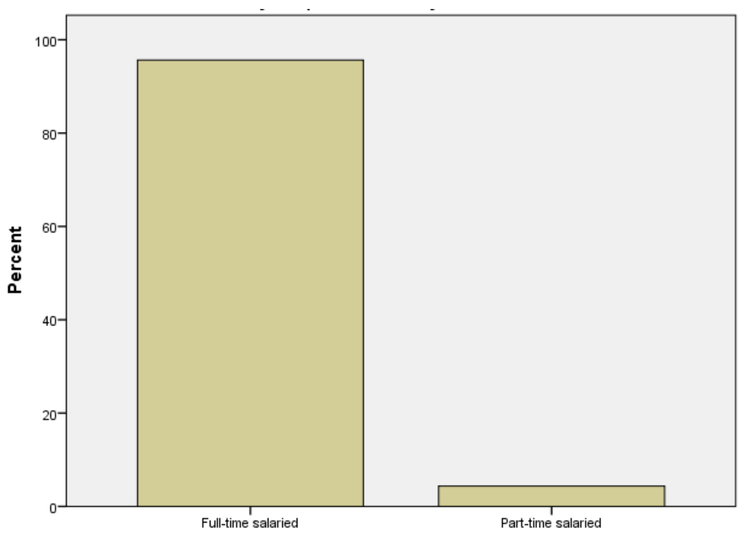

Figure 11 Demographic of questionnaire respondents – tenure of respondent

The questionnaire was seeking responses from appropriately experienced members of staff and therefore it was necessary to establish the relative length of service of respondents. The majority had a minimum of five years' service in their role and a substantial minority had been in post for more than ten years, as shown in the bar chart below (Figure 12). A small number of responses from staff members with less than two years of service were removed from the data since more robust data would come from experienced and therefore more knowledgeable staff members. One respondent had less than two years' service with the current PEI but more than 10 years in a similar role in another PEI so this individual's set of responses was included.

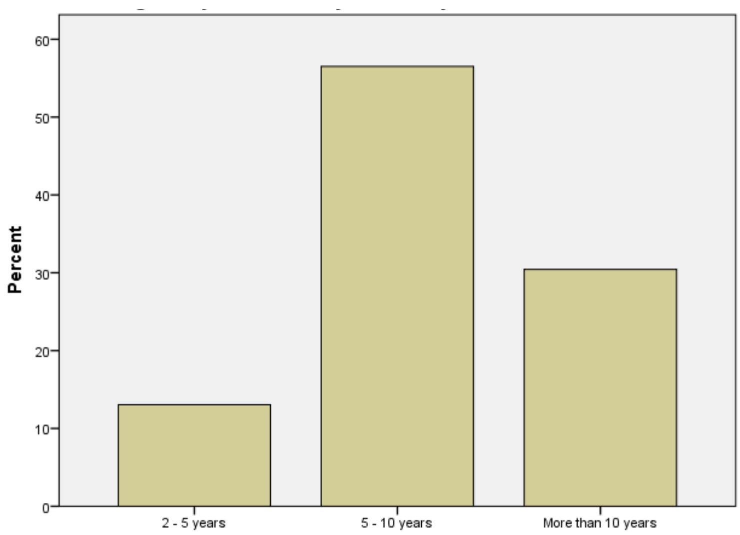

Figure 12 Demographic of questionnaire respondents – relative experience of staff members

It was also possible to test the correlation between length of time in post with attitudes as to whether engineer registration processes are consistent across all PEIs, and attitudes to the usefulness of the UK-SPEC and AHEP 3 publications, and this is examined later in this section.

To establish a pattern of how the PEIs interact with each other, data was requested as to how regularly the staff members correspond or otherwise interact with the other PEIs. The overwhelming majority indicated that they interact with other PEIs quite rarely and a smaller percentage implied that their interaction was more regular in nature. Very few answered that they interact regularly with other PEIs.

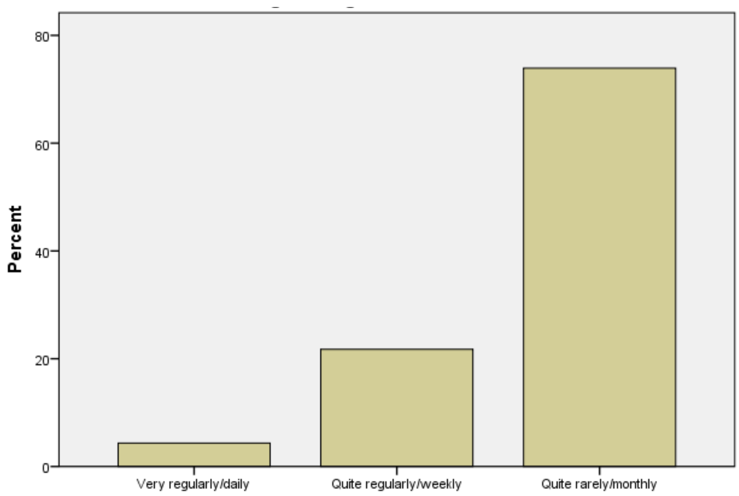

Figure 13 Frequency of interaction between PEIs

To complete this part of the analysis, staff members were asked to indicate how often they corresponded with or generally interacted with the EC itself. It can be seen that there is far more interaction with the EC than between the individual PEIs.

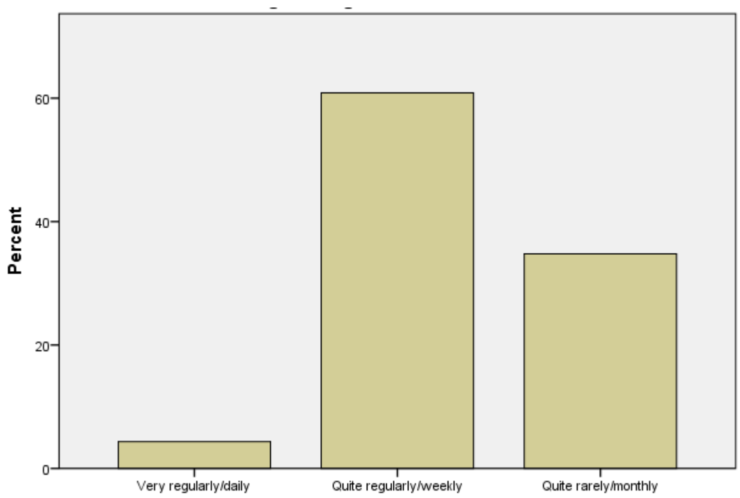

Figure 14 Frequency of interaction between PEIs and the EC

The correlation between these data and the relative sizes of PEI was examined using SPSS software. The Spearman's rho correlation test was applied since this is the accepted test for the examination of non-parametric data. Table 11 below shows an extract from the SPSS output; the correlation coefficient of -.471 (coloured red) with one asterisk indicates a moderate negative correlation within 5% (the 2-tailed significance figure of 0.031 is less than 0.05). The data therefore infers that the smaller PEIs (according to raw member count) are less likely to regularly correspond or otherwise interact with other PEIs than the larger institutions. There is, however, no significant correlation between the size of PEI and regularity of interaction with the EC, since the 2-tailed significance figure in this case is greater than 0.05.

Table 11 Correlations between PEI size (raw member count) and interactions with other PEIs and the EC

			Interaction with other PEIs	**Interaction with EC**
Spearman's rho	**Size of PEI (small, medium or large)**	Correlation Coefficient	**-.471***	-0.400
		Sig. (2-tailed)	**0.031**	0.072
		N	82	82

The same test was applied according to the number of members of each PEI holding a membership category commensurate with EC registration, as defined above, and this is shown in Table 12. It is found in this case that PEIs with fewer engineer members tend to interact less regularly with each other and with the EC itself.

Table 12 Correlations between PEI size (engineer members) and interactions with other PEIs and the EC

			Interaction with other PEIs	**Interaction with EC**
Spearman's rho	**Number of EC registrant members of PEI**	Correlation Coefficient	**-.460***	**-.461***
		Sig. (2-tailed)	**0.036**	**0.035**
		N	82	82

This is an interesting point of discussion since it affirms in part the hypothesis that smaller PEIs are less well represented than the larger PEIs and hence wield less influence.

The following questions ask more directly about participants' attitudes to the EC and how representative they perceive it to be. When questioned about whether the EC represents the interests of all 35 PEIs equally, there was a slight majority that agreed or strongly agreed, though a large minority provided a neutral answer and a small percentage even disagreed (Figure 15). When questioned about whether the structure of the EC enables all PEIs to be represented equally in matters of policy, there was an even less positive response: in this case the neutral respondents neither agreeing nor disagreeing outweighed those who agreed (Figure 16).

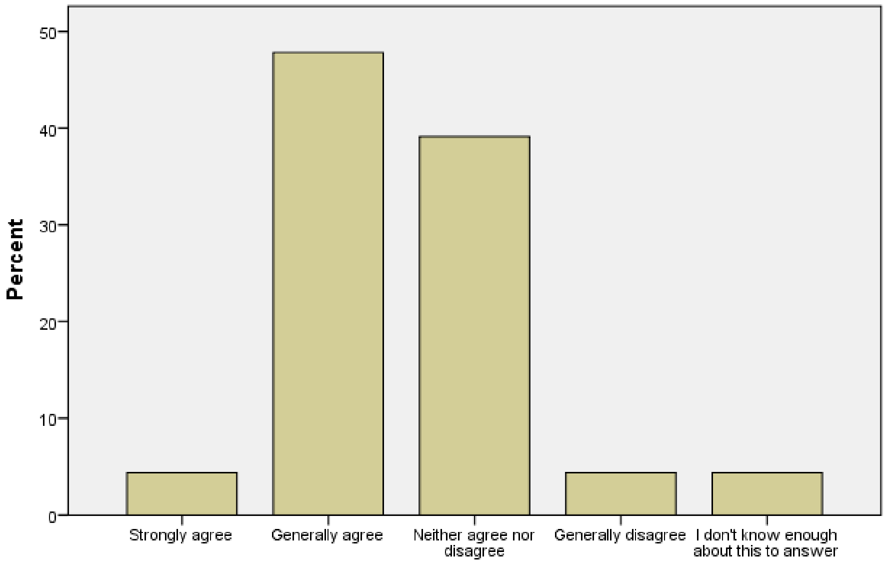

Figure 15 Participants believing that the EC represents all PEIs equally

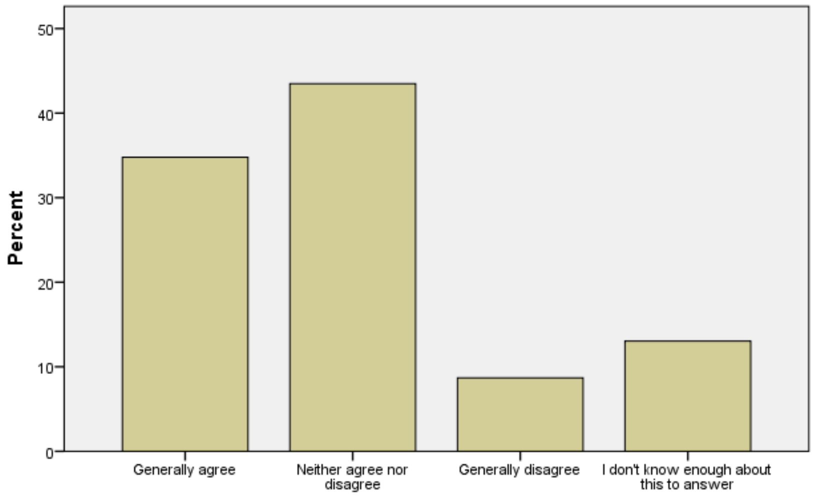

Figure 16 Participants believing EC's structure allows all PEIs to be equally represented in policy

There was no correlation found between these data and PEI size and relative number of engineer members. However, it was found (perhaps unsurprisingly) that those participants who interact regularly with the EC tend to believe the most strongly that the EC is representative of all PEIs in matters of policy, as demonstrated in Table 13 below, though there can be no correlation implied between those staff members who interact regularly with the EC and the view that the EC represents the interests of all PEIs equally.

Table 13 Correlations between regularity of interactions and belief that EC represents all PEIs

			EC represents interests of all PEIs	EC represents all PEIs in policy
Spearman's rho	**Interaction with EC**	Correlation Coefficient	0.427	**.518***
		Sig. (2-tailed)	0.054	**0.016**
		N	82	82

The questionnaire next asked whether participants had confidence that the UK-SPEC is a useful and accessible publication. A clear majority agreed generally that it is, as shown in Figure 17 below.

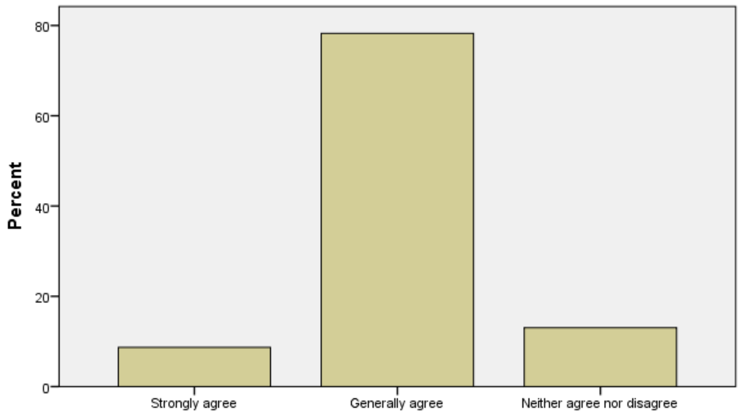

Figure 17 Participants believing that the UK-SPEC is a useful and accessible document

There were no correlations evident here, which suggests that this a widely held view among all the PEIs, irrespective of size of institution or any other demographic.

The questionnaire further asked about whether each PEI had been involved in the drafting of the PECs listed in the UK-SPEC and the picture was more mixed in this instance, with a large number of respondents stating that their PEI was not at all involved (Figure 18).

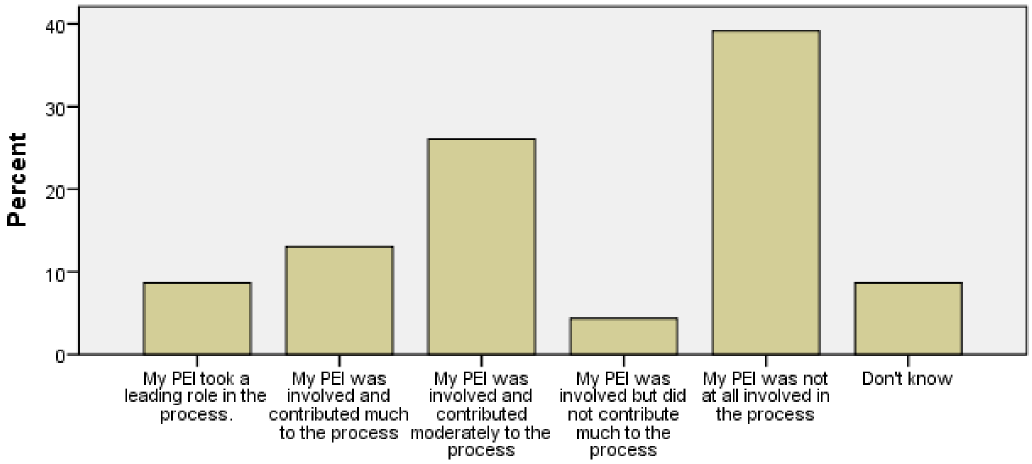

Figure 18 PEIs involved in drafting the PECs

Clearly it was necessary here to investigate any possible correlations. A strong negative correlation was found between the size of PEI by raw member count and the likelihood of the PEI having been involved in drafting the PECs. Likewise, a strong negative correlation was evident concerning the PEI size with reference to engineer members. This is shown in Table 14 below.

Table 14 Correlations between PEI involvement in drafting of PECs and PEI size (raw member count and number of EC registrant members)

			Size of PEI (small, medium or large)	**Number of EC registrant members of PEI**
Spearman's rho	**Involved in drafting PECs**	Correlation Coefficient	**-.609****	**-.676****
		Sig. (2-tailed)	**0.003**	**0.001**
		N	82	82

These correlations would appear to confirm an early hypothesis in the work that the larger PEIs enjoy more influence in the EC and they had thus been instrumental in drafting the PECs.

The next questions then attempt to elicit attitudes to whether the PECs are considered to be of equal value and use across the various engineering disciplines. Respondents who indicate that they consider the PECs can readily be applied to all engineering disciplines form a large majority, as shown in Figure 19, which shows a good degree of confidence, notwithstanding the fact that there were no respondents who strongly agreed. The picture is less positive, however, when considering whether the PECs are the best way to establish competence in the actual discipline represented by the respondent, as shown in Figure 20.

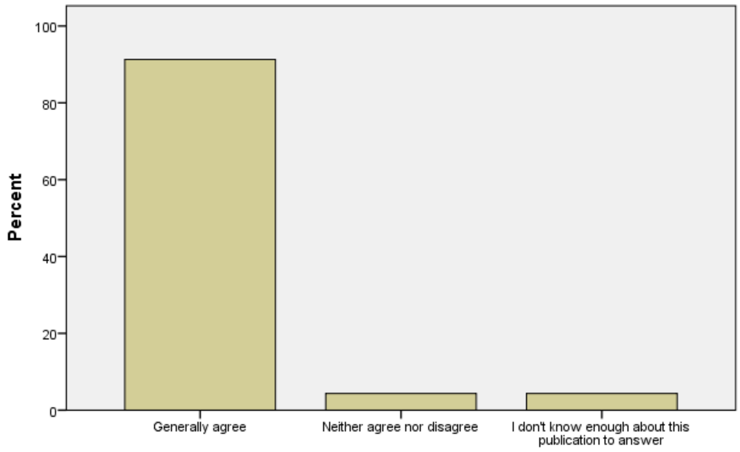

Figure 19 Participants believing that PECs can be readily applied to all engineering disciplines

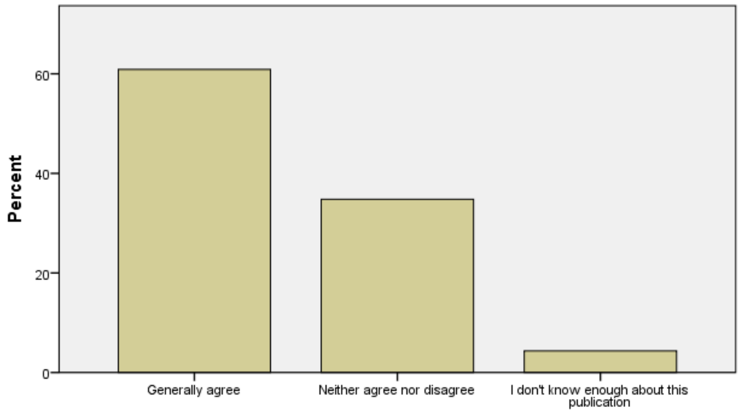

Figure 20 Participants believing that PECs are best way to establish competence in own discipline

There were no correlations to these data with institution size, job role or length of experience of staff member; though a moderate positive correlation was discovered between the question of the best way to establish competence in the individual engineering discipline and those respondents who were involved in the drafting of the PECs. This is shown in Table 15 below.

Table 15 Correlation between PEIs involved in drafting PECs and belief of applicability to own discipline

			PECs applicable to my discipline
Spearman's rho	**Involved in drafting PECs**	Correlation Coefficient	**.507***
		Sig. (2-tailed)	**0.019**
		N	82

This correlation is perhaps not surprising since it suggests that those PEIs who were involved in drafting the PECs have more confidence in their applicability to their own engineering discipline.

A point that arose in the literature and in the exploratory interviews was that there is a perceived lack of consistency with procedures and methods for engineer registration across the various PEIs. The respondents were therefore asked for their view on this point. The bar chart shown in Figure 21 below shows that there is some likelihood that procedures are inconsistent, the largest number of responses at around 50% being “neither agree not disagree” and some 20% actively disagreeing. This result would appear to bear out the earlier hypothesis that there is indeed some inconsistency of approach to registration.

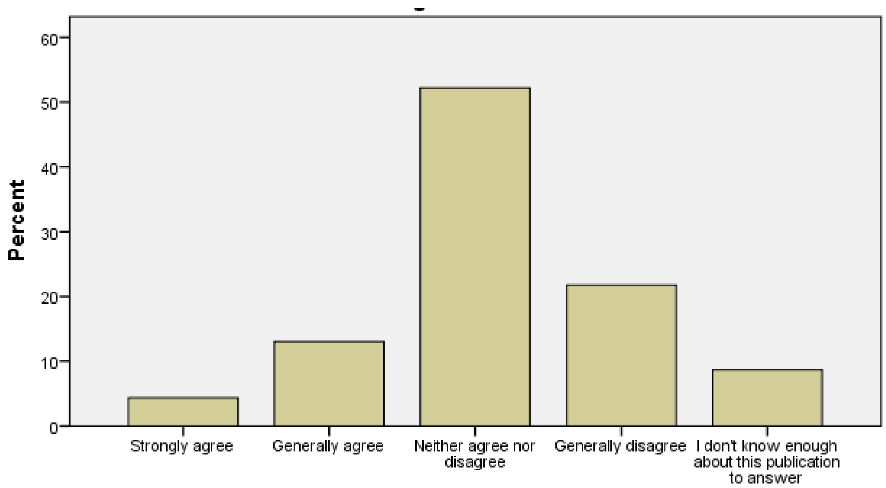

Figure 21 Participants believing there is a consistent approach to engineer registration in all PEIs

Again, it is useful to seek correlations with this piece of data, though only one correlation is evident: that those who consider the PECs to be useful and applicable to their own discipline tend to believe the most that there is a consistent approach to engineer registration. This is shown in Table 16 below.

Table 16 Correlation between belief in consistency of approaches to engineer registration and PECs applicability to own discipline

			PECs applicable to my discipline
Spearman's rho	**Consistency of engineer registration procedures**	Correlation Coefficient	**.468***
		Sig. (2-tailed)	**0.032**
		N	82

The fact that there is only one moderate correlation with this piece of data indicates that it is a widely held belief across all respondents that there is indeed an inconsistency of approach to engineer registration, and this bears out the views recorded during the exploratory interviews.

The last section of the questionnaire deals with accreditation, and the literature and exploratory interviews suggest that there are three ways in which PEIs accredit courses:

- Independently;
- In collaboration with other PEIs;
- As part of a consortium (for example the JBM mentioned in Section 2.7.1).

Some PEIs use all three methods, some use the first two and others only accredit courses independently. The percentages of PEIs using the various accreditation methods are shown in Figure 22 below.

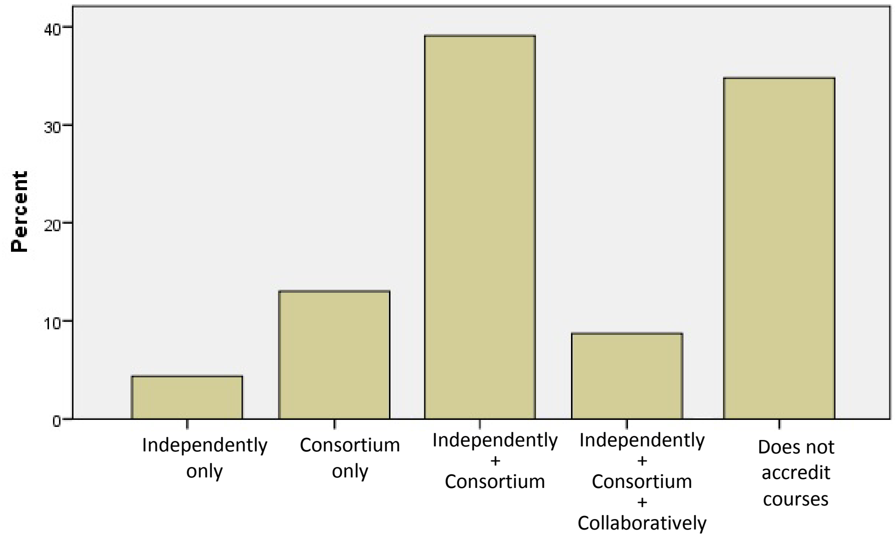

Figure 22 Accreditation methods used by PEIs

It can be seen that there is substantial minority of PEIs that do not accredit courses, plus there is a large number of PEIs dependent upon a consortium approach, and this probably implies a lack of expertise in the smaller institutions. It is therefore subsequently of interest to catalogue attitudes to the AHEP 3 publication and investigate correlations between these data and the relative sizes of institutions.

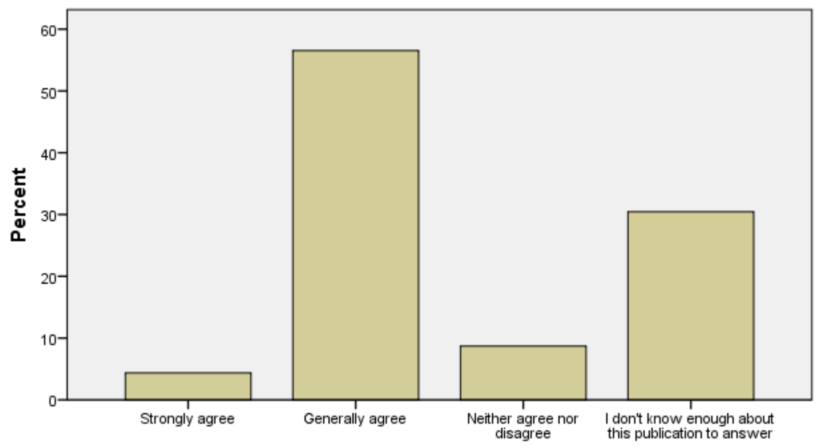

Figure 23 Participants believing that AHEP 3 is a useful and accessible publication

As can be seen in Figure 23, there is a substantial level of confidence in the AHEP 3 publication, though there is a large minority who do not know enough about the document to comment. This is of course because many PEIs either do not accredit courses or accredit courses as part of a consortium (as shown in

Figure 22), and many of the respondents to the questionnaire are involved in membership and registration (see Figure 10) and would not necessarily be knowledgeable about accreditation. There is a similar spread of opinion shown in Figure 24 below where respondents were asked their opinion on the suitability of AHEP 3 across all engineering disciplines.

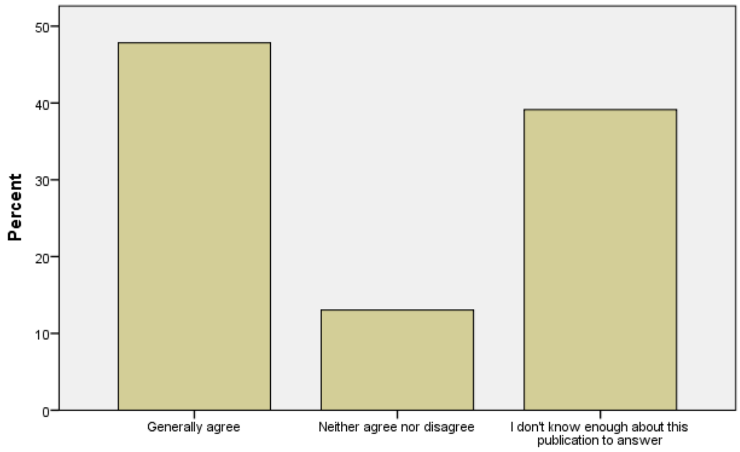

Figure 24 Participants believing that AHEP 3 can be readily applied to all engineering disciplines

Clearly the correlations here need to be investigated. Table 17 indicates that there is a moderate positive correlation between those PEI staff members who interact regularly with the EC and their attitudes to the AHEP 3 publication. The size of PEI (using both definitions of size) also correlates with attitudes to AHEP 3: the smaller the institution, the less likely are participants to hold positive opinions about AHEP 3. Again this bears out the fact that smaller institutions are less likely to carry out course accreditations.

Table 17 Correlation between attitudes to AHEP 3, frequency of interaction with EC, and size of PEI (raw member count and engineer registrant numbers)

			Interaction with EC	**Size of PEI (small, medium or large)**	**Number of EC registrant members of PEI**
Spearman's rho	**AHEP 3 useful and accessible**	Correlation Coefficient	**.496***	**-.615****	**-.495***
		Sig. (2-tailed)	**0.022**	**0.003**	**0.023**
		N	82	82	82
	AHEP 3 applicable to all disciplines	Correlation Coefficient	**.531***	**-.548***	-0.426
		Sig. (2-tailed)	**0.013**	**0.010**	0.054
		N	82	82	82

4.5 Analysis of in-depth semi-structured interviews

The in-depth semi-structured interviews were carried out with 14 respondents representing a wide range of experience and knowledge as described in Section 3.2.5. The questions used to structure the interviews are reproduced in Appendix 6. The purpose of the interviews was to build upon what had already been discovered from the literature, the exploratory interviews and the questionnaire survey, with particular regard to research objectives 4, 5, 6, 7, 8 and 9:

Objective 4 *– Examine how BSE study programmes are developed and the process of professional accreditation in the UK.*

Objective 5 *– Examine the educational and professional requirements for engineers to be registered to practise in the UK and overseas.*

Objective 6 *– Investigate and critically analyse international systems which are attempting to facilitate international transparency of engineering qualifications.*

Objective 7 *– Compare and contrast the main systems and procedures overseas for accrediting engineering academic programmes, recognising engineering competencies and registering/licencing engineers.*

Objective 8 *– Elicit views as to the perceived value of a UK engineering education when practising abroad.*

Objective 9 *– Elicit views about what an education and training model should encompass to facilitate internationalism in BSE education.*

The objectives are quite numerous and wide ranging and it was therefore not expected that each respondent would be able to provide the same level of detailed response to every question. However, a wide range of interviewees was selected, such that each respondent would have detailed expert knowledge about a significant number of the objectives, even if there were other areas about which they were relatively ignorant. For consistency, the same questions and outline structure were utilised for each interview, though the flexible nature of the process enabled the interviewer to vary the focus of each interview as necessary on an ad hoc basis.

Some respondents, by virtue of their profession had more knowledge and held stronger opinions about certain aspects than others; this was expected and the interview processes were managed accordingly. To recap, the interviewees were as follows:

- Three members of academic staff, specialising in BSE and AE at three different UK universities: These respondents were expected to be able to provide rich factual data and informed opinions covering primarily objectives 4 and 5. Because all three respondents were very experienced in a university environment, they were also able to articulate valid views concerning objectives 6, 7, 8 and 9.

- Three overseas senior members of academic staff, specialising in BSE related engineering disciplines in Australia, Sri Lanka and Hong Kong: These interviewees were able to contribute knowledge and informed opinions concerning objectives 5, 6, 7, 8 and 9.

- Three senior practising BSEs with overseas experience: These interviewees were expected to contribute knowledge and valid opinions concerning objectives 5, 6, 8 and 9.

- Two senior BSEs, educated in the UK and practicing in UK BSE consultancies: These interviewees were expected to contribute knowledge and valid opinions concerning objectives 5, 6, 7, 8 and 9.

- Three senior members of PEI staff, one from the CIBSE, one from the EI and one from the IET: These interviewees were expected to contribute expert knowledge and informed opinions relating to all the objectives listed above.

The data were analysed thematically and are summarised in the following discussions, which attempt to capture a consensus of the responses from all interviewees.

4.5.1 The influence of the CIBSE, the EC, and the WSDA agreements

The interviewees who are academic staff in universities, including those practicing overseas, agreed that the courses they manage, deliver and (in most cases) helped to develop are influenced by the UK-SPEC and AHEP publications, though in the cases of overseas courses much of this influence is indirect. The UK academics stated that they found the CIBSE document, *Guidance notes on the submission of documentation for accreditation of academic programmes* (CIBSE, 2012), of particular use, though the overseas academics pointed to local publications from their own national regulatory bodies. In Australia, very detailed and comprehensive guidance is provided by Engineers Australia (the Australian regulatory body for engineering), Hong Kong's own Engineering Council also publishes guidance, as does Sri Lanka's Engineering Council, though the interviewees suggested that this guidance is largely derivative of WSDA (and to some extent EC) documentation. In each case the overseas publications were generic and applied to engineering courses as a whole, and there was no specific guidance about BSE courses. It was suggested that throughout much of the developing world similar generic guidance is published for the setting up of engineering courses, usually designed to fit WSDA protocols, but detailed specialist guidance on BSE courses, such as that published by the CIBSE, is rare.

In Australia there are, unsurprisingly, several parallels with the UK HE system, and BSE courses are largely developed and delivered along similar lines to those offered in UK universities, though the curricula naturally tend to reflect local requirements. There is input and support from the local CIBSE Region, though course accreditation is dealt with via the local regulatory body, Engineers Australia, which in turn is a signatory to the WA and SA agreements. In Hong Kong the CIBSE has a strong local presence and working practices similar to those in the UK are often seen, so it is perhaps unsurprising that many of the BSE courses offered at undergraduate and postgraduate level are franchised from UK institutions, though there are a number of locally developed Masters courses. Again, accreditation is effected via the local regulatory body, the Hong Kong Engineering Council. In Sri Lanka there are no dedicated BSE undergraduate degrees, though there are one or two post graduate specialist Masters degrees. Undergraduate specialist education in BSE is available up to HND level through college courses validated by Edexcel-Pearson, and BSEs, if they wish to progress to degree level, must do so by taking other pure engineering degrees. Anecdotally, two interviewees suggested that a great many BSEs in Sri Lanka are immigrants from India and other countries. A number of the interviewees had experience either working in China or working with Chinese companies and suggested that the Chinese system has some similarities with what has been described above, with the regulatory body retaining responsibility for accreditation and there being a general overarching aim of mutual recognition of engineering qualifications so that foreign engineers may be allowed to practice. There is, however, more North American influence via the ABET in China and this is also found in many Middle Eastern countries. Although ABET does not actually accredit overseas programmes, it does offer guidance to assist in the design of programmes to encourage mutual international recognition and transparency. In the BSE field there is considerable influence from ASHRAE, thus many BSE courses worldwide tend to fit within the requirements of the WA and SA agreements.

In this work, the prevalence of the WA and SA agreements is of considerable importance in the wish to improve the international mobility prospects of UK trained engineers, and this consequently influences the new education and training model. The early supposition in this work that the PECs set out in the UK-SPEC may result in some cultural discomfiture in the way that they are drafted from a Western standpoint was considered to be a true and valid criticism to an extent, though most of the respondents felt that the strength of the EC approach is that it dovetails so neatly with the WSDA graduate and professional competencies. It was generally agreed that similar charges of cultural awkwardness could well be levelled against the requirements of the WSDA competencies, but all respondents with a working knowledge of these believed that the right approach was being taken, additionally it is most certainly possible to allow local interpretations, and most jurisdictions are either compliant or working towards compliance.

4.5.2 Industry involvement in BSE courses

There were several views about the involvement of industry in the design and operation of BSE courses in the UK and overseas. Care has been taken not to over-generalise in the following discussion but particular themes and consistent viewpoints most definitely emerged.

As a general principle it would seem that it is common across the world that when designing new engineering courses, local and national employers and professional bodies are usually involved as advisers and consultants through informal, as well as formal, channels. This would appear to make good sense given the highly vocational nature of engineering programmes generally and BSE programmes in particular. The UK academics and practitioners reported that it is quite normal for the relationship with industrial and professional advisers to continue through industrial liaison committees and the like once courses become established, and this helps to ensure that programmes remain up to date and reflective of industry requirements. This picture is echoed to a greater or lesser extent around the world, though it was noted by more than one respondent that the UK's systems for industrial and professional involvement in higher education seem better developed and the practice is more ingrained than in other parts of the world. Industrial liaison does, however, exist in various guises around the world and it is best not to over-generalise on this point.

For delivery of teaching, as a general rule UK universities tend to prefer employing highly academically qualified lecturers to carry out most of the teaching, and such personnel also carry out scholarly activities and contribute to the universities' research activities. Industrial partners and professional bodies normally contribute on an ongoing basis mainly by delivering occasional guest lectures, and providing support and advice at things like validation events and accreditation visits. The pattern observed in many overseas locations is that there is more of a tendency to employ practicing engineers to complement the role of pure academics by carrying out teaching on a part-time basis. Course managers are likely to be full-time academics, while significant proportions of teaching are carried out by part-time or contracted staff members who are also in professional practice outside of their teaching role. Again, this is not necessarily true worldwide, certainly in Australia a closer parallel to the UK system can be observed, but the experiences of the interviewees suggest that there is indeed substance to this general assertion. There are undoubtedly strengths and weaknesses inherent in both approaches: pure academics tend to be less able to relate pure engineering concepts to realistic vocational contexts, while practitioners who teach part-time are in general more able to provide a realistic perspective to learning. Conversely part-time teachers often find it difficult to contribute to scholarly activities and research, and a good research profile is known to feed positively into ongoing course development.

In the context of this research subject, this last point is perhaps moot, but professional body and industry involvement in courses through formal and informal channels is generally recognised as maintaining courses as relevant and applicable to the professional discipline served.

4.5.3 Content of BSE courses

In discussions with several of the respondents it was established that a very similar approach is taken to the content of BSE courses in different parts of the world, though in some countries (Sri Lanka is one example, though there are others) there are no BSE degree courses available and registered BSEs tend to have graduated from Mechanical Engineering or sometimes Electrical Engineering degree courses. Engineers with lower levels of responsibility usually progress through from HNC and HND programmes (which the Edexcel-Pearson qualifications agency exports throughout the world) or through similar locally developed programmes. Such programmes may be locally accredited and come under the remit of the DA agreement for Engineering Technicians, though, as previously described, this part of the industry is much more unregulated, and Engineering Technicians are far less likely to be registered and/or licenced than Incorporated and Chartered Engineers. As previously discussed, the Edexcel-Pearson model allows a diet of units to be selected by the institution from a repository, such that the course overall meets local needs, thus an HNC delivered in the UK might focus on units which teach building heating, while in Dubai (for example) the units focussing on the cooling of buildings would be likely to feature more prominently.

In degree courses a similar trend is observed, where specialist modules can provide individual courses with a local flavour as necessary. As would be expected, however, there is a good deal of common content that finds its way into all BSE courses, and similar core engineering fundamentals appear universally. The range of subjects that should be taught in a BSE degree when factored against the requirements for a fundamental engineering skillset is acknowledged as a real problem for course design, though it was generally agreed – particularly by the academic respondents – that much of the mathematical and pure engineering skills are perhaps of secondary importance in comparison to the ability to apply engineering logic in the in design of energy efficient and sustainable systems for buildings. In any case, it was argued, most BSEs do not work from first principles and utilise software packages for much of their analytical work, and BSE courses should perhaps reflect this more.

Most of the interviewees held a view that suggests, as a general observation, that overseas HEIs often deliver a greater proportion of non-contextualised pure engineering learning than is characteristic in the UK approach; that is to say that subjects like mathematics, science and engineering principles are more likely to be taught in a pure form and less likely to be taught in a vocational setting than in the UK. In UK BSE courses, no doubt largely due to the advice provided by the CIBSE (CIBSE, 2012), much of the learning is delivered though individual and group technical project simulations relating to real buildings, and this helps to contextualise a great deal of the learning. All respondents championed this approach and most agreed that this style of teaching and learning is not seen so often in many overseas locations. The reliance on projects is also used as a tool in an attempt to overcome the difficulty posed by UK students joining courses while lacking some of the basic mathematical and engineering fundamental knowledge – it is argued that applying learning to real situations and scenarios can engage such students to assimilate their learning and read more deeply into the subject matter. In addition it was believed generally by the interviewees that UK courses tend to be much stronger on the teaching of softer skills associated with engineering such as management, finance, commerce and law, and this, while necessary, can be to the detriment of fundamental engineering knowledge and skills.

A central premise of UK higher education is that the university experience primarily enables people to assimilate higher level academic skills (including research capabilities), notwithstanding the fact that these skills can be highly vocational in nature. For people to become occupationally competent they must be given opportunity to apply these higher level skills and knowledge in a professional setting. There were a range of views on this subject among the interviewees: practitioners argued, perhaps not surprisingly, that teaching institutions should be responsive to industry and be prepared to equip graduates directly with skills that are needed in professional practice, though all accepted that workplace training is vital to occupational competence. It was generally believed that there is more likelihood in many overseas locations of courses teaching skills which are directly related to workplace practice than in the UK, for example the use of computer aided design (CAD) software applications is taught in many countries as part of the fundamental engineering skillset.

It was suggested by some of the practitioner respondents that educational institutions often tend to be "behind the curve" when assimilating industry standard software tools into their teaching, and universities are often slow to integrate new concepts or methods of work into courses (for example BIM). The academic respondents largely countered this claim, suggesting that university courses do indeed encourage the use of industry standard software and attempt to use this to contextualise learning, however, it is argued that university programmes must not be allowed to become training courses for proprietary software applications. It was suggested by some of the respondents that some overseas BSE courses (particularly in Hong Kong and China) teach skills like the use of CAD and thermal modelling software as discrete topics as an integral part of students' fundamental engineering skillset. The practitioner respondents generally felt that this was likely to be a worthwhile proposition if there was room in the course for such an approach, given that there is already a very wide range of material that must be fit into BSE courses. It was generally accepted by the interviewees, however, that if this approach is over-used to the detriment of more research focussed learning, it can lead to institutions producing graduates who may well be very proficient in a relatively narrow range of skills, but may possibly lack the ability to question established procedures and take responsibility for decision making in engineering projects. That is to say, such an education may provide suitable competencies for Technicians and Technologists, but not for Engineers.

Since BSE is such a highly international profession, it could perhaps be seen as unfortunate (though in many ways it is inevitable), that very often subject matter is taught which has a distinctly local flavour. For example, UK BSE courses ally much of their teaching of systems design to UK working practices, UK law, UK Building Regulations and UK codes of practice. This is of course ideal for ensuring that graduates who go on to practice in the UK have the appropriate knowledge, but some respondents felt that this to some extent smacks of a somewhat parochial and insular approach. The same charge could of course be levelled at many overseas BSE courses, however, it was pointed out that in many countries with a link to the UK via the British Commonwealth, local regulations and methods of work are often similar to those in the UK, and much of the technical guidance comes from CIBSE Guides, which are generally well accepted internationally. In countries with no link to Great Britain, often American practices are taught, and ASHRAE publications and practical guidance are used. However, it was also argued that learning to apply regulations and standards is not necessarily a defining issue: this constitutes a transferable skill and engineers working abroad are generally able to cope with different sets of regulations.

It was, however, suggested that engineers moving overseas do sometimes find that local customs and cultural differences can lead to some discomfiture and subsequent difficulties in working practices. It was felt generally (though many respondents had not considered the question until it was raised in the context of this work) that respective cultural differences and attitudes can affect the way that engineering ethics are interpreted in different parts of the world and BSE courses generally do not equip graduates to deal with this. The practitioner interviewees cited examples of UK BSEs experiencing considerable professional difficulties when settling into foreign cultures and, although it was not necessarily expected that engineers could be taught all they needed to know to work in any country in the world, it was considered that trainees should be given a flavour of what to expect in common destination countries. Most respondents were open to the notion that a consideration of engineering ethics, an examination of what constitutes ethical behaviour, and an overview of foreign cultural values could be a good addition to BSE courses. Differing attitudes to sustainable development were cited as a particular sticking point, where Western and European values can be very much at odds with those in the developing world. Since BSE courses are, as has been already reported, highly vocational in nature wherever in the world they are taught, it is difficult to find space in course structures to fit new subjects, however, it was suggested that engineering ethics is usually included as part of design project modules, so teaching these from a slightly different angle need not displace anything meaningful from courses. It was also suggested that international exchanges of students and a semester or even a year spent overseas during education and training could be very useful for students.

According to all respondents who had knowledge of overseas programmes, BSE courses throughout the world tend to facilitate part-time attendance for employed students. BSE appears to hold a similar standing across the world as it does in the UK; that it is a highly specialist profession and young people tend not to select it as a career path, and many BSE students consequently are employed adults who are self-motivated, often self-supporting and with a range of prior experience and knowledge. The main difference seen in many countries is that part-time university courses often require evening and weekend attendance at university, something found much less in the UK.

In summary, it was suggested by most respondents that the approach to teaching BSE in the UK is largely fit for purpose and learning can be applied in other cultures fairly well. All respondents who expressed a view commented that the use of practical projects to contextualise learning is good practice. Some respondents viewed UK courses to be somewhat light on engineering fundamentals, though conceded that when such a wide range of practical technologies must be included, teaching engineering systems in vocational context to some extent would overcome this deficiency.

4.5.4 Course accreditation processes

Some of the interviewees related experiences in recent years where they had observed, or been part of, CIBSE accreditation panels travelling overseas to accredit BSE programmes abroad. Indeed accreditation of any overseas BSE programmes by the CIBSE is theoretically possible in the same way as it is for UK institutions, though this is most certainly a resource intensive process. However, as the WA and SA agreements have gained momentum and increased their influence in recent years, it has consequently become less common for UK PEIs to accredit overseas programmes. The WA and SA agreements mean that in member countries courses can be accredited by their own local regulatory body using whatever local mechanism is appropriate, and as long as WSDA protocols and standards are followed, recognition in other signatory countries is assured.

A particular problem linked with this approach is that PEIs like the CIBSE must deal regularly with an ever increasing number of registration and membership enquiries from engineers with qualifications which may be accredited under the WA and SA agreements, but are not accredited by the PEI itself. Applications from candidates with non-accredited degrees are normally judged individually on merit by a panel of PEI appointed experts, in the CIBSE there exists an "Individual Case Panel" and other PEIs have similar structures to deal with non-standard applications. Such panels have seen a substantially increased workload in recent years as more applications are received from engineers with overseas degree qualifications which may sit within (or without) the WA or SA agreements. Several respondents remarked that this process is somewhat admin intensive at the moment, but is likely to settle as the WA and SA systems become more embedded within each PEI's systems and procedures.

4.5.5 Registration of engineers

All respondents with knowledge of engineering registrations overseas suggested that the similar registration categories to the EC and WSDA titles tend to be found throughout the world, although unsurprisingly there are local variants. In most jurisdictions there appears to be broad agreement about the professional status of Engineers and Incorporated Engineers (also very commonly known as Engineering Technologists), though local variations in nomenclature and definition inevitably occur. There is less agreement about Engineering Technicians and their equivalents, and some countries have a number of different titles, which can confuse the issue somewhat. Since this work considers only degree qualified engineering professionals the discussions surrounding the lower grades have not been considered in any depth.

In most cases the competencies specified for engineer registration show considerable parallels with those specified in the WA and SA agreements, since there is a very real impetus particularly in the developing world to recognise the international nature of engineering and the benefits of mutual recognition of qualifications. Only one of the interviewees had any experience of dealing with the EUR-ACE system, having been an EC representative with the ENAEE, and considered that since EUR-ACE neatly fits within the WA and SA agreements, that there is no particular issue to examine here. This respondent reminded the interviewer that EUR-ACE only considers the accreditation of academic qualifications in engineering, while the WA and SA agreements also set standards for professional competence. Thus the WA and SA competencies should be properly addressed in the proposed education and training model to promote internationalism.

Four of the respondents with extensive overseas experience related that in many countries – even some which are signatories to the WA and SA agreements – there are no coherent systems for recognising, evaluating and validating professional experience gained in the workplace, and hence engineer or technologist registration and/or licencing can often be awarded based upon academic qualification only. Other interviewees, albeit with less overseas experience, concurred with this observation. The EC's insistence and management of a coherent system of recognising and assessing professional competencies (notwithstanding the inconsistencies in approach to registration between some of the PEIs highlighted earlier) was seen as very positive practice and some of the overseas respondents considered the EC to be something of a world leader in this area.

There was some discussion with all interviewees about the lack of parity between IEng and CEng registrants and all who expressed an opinion felt that this situation is unhelpful and some steps should be taken to address this. At the time of writing the WA and SA agreements are undergoing review with the intention of delineating the two grades more precisely to ensure that the Engineering Technologist (IEng equivalent) grade is better recognised, and it was reported that the EC is party to this process.

4.5.6 Perceptions about UK BSEs

Several of the interviewees suggested strongly that it is a common perception in several overseas destinations that UK trained BSEs tend to exhibit high levels of occupational competence at a comparatively young age and are consequently generally held in high regard. There is also a view that UK professionals tend towards more self-confidence and are ready to accept considerable responsibility early in their career.

Many respondents reflected that this is likely due in large part to the incidental (though often unstructured or even ad hoc) work based learning that takes place alongside part-time college and university attendance in the UK, a situation that is common in the education and training of BSEs. There may be some merit to this claim, but many other countries also have part-time course delivery for students in full-time employment, so it should follow that these trainees would exhibit similar traits. It was also pointed out that in the UK there is, because of the lack of visibility of the BSE profession, a constant and ongoing shortage of qualified BSEs, so young engineers are often forced into accepting high levels of responsibility early in their career. This argument also seems logical but many other countries experience similar problems attracting people into the industry.

It was also suggested by one or two respondents that in many world cultures there is a tendency towards deference to Europeans and North Americans, which could explain to some extent the esteem with which UK engineers appear to be held. This is, however, a complex sociological question, an interesting discussion point, but a detailed analysis of this question would be somewhat outside the remit of this work.

Several of the interviewees reflected that the UK system of engineer registration is more mature and coherent than comparable systems found in many parts of the world and it therefore better facilitates the recognition, assimilation and assessment of professional competencies in the workplace. There is undoubtedly merit in this argument. The structure and scope of professional training and experience would appear to be a key factor here: although much on the job experience for BSEs in the UK tends in many cases to be largely ad hoc and unstructured, it is considered that the CIBSE provides engineers and their employers with some very useful advice and guidance on how to meet professional competencies in the workplace. CIBSE also has an accreditation scheme for in-company graduate training courses, this being designed to enable graduates to work purposefully towards registration under the guidance of a workplace mentor. Views from all respondents, home and abroad, indicate a high degree of confidence with CIBSE systems for accreditation, registration and membership, which also goes to make UK BSE registrants highly desirable.

There is of course no one reason as to why UK BSEs seem to be viewed in such a positive light across much of the world, but undoubtedly the truth is a combination of the points described above.

4.6 Summary

Hypotheses and suppositions advanced earlier in this work have been re-examined in the light of the data analysis presented in this chapter to advance the prospect of an education and training model for BSE that facilitates international mobility of UK registrants.

There are undoubtedly issues surrounding the way that the EC is structured and the way it represents the various branches of engineering. The analysis appears to bear out the early hypothesis in the work that smaller PEIs are not as involved and not as well represented in EC affairs as they might be. It is also clear that the smaller and less influential PEIs were not as involved in the drafting of the UK-SPEC and the PECs, notwithstanding the EC's attempts to involve representative cross sections of PEIs in the original process and in more recent reviews and updates. This is undoubtedly a subject from which further research projects could stem, but in the context of BSE education and training it is not profitable to examine these points in any more detail since the CIBSE emerges as a strong and assured voice representing the BSE industry at home and abroad. As a medium-sized PEI it does not appear to be unduly overshadowed by the larger and possibly more influential institutions.

It is also true that the EC's influence on BSE education and training is considerable, through systems engendered by the AHEP and UK-SPEC publications, though the perception is that this is generally beneficial both at home and abroad. An early hypothesis that such influence may not be a comfortable fit in many overseas destinations seems to be largely unfounded, given the views espoused in the semi-structured interviews, several of these being from experts with considerable overseas experience. From a UK perspective, the PECs set out in the UK-SPEC are generally considered to be fit for purpose in the field of BSE, notwithstanding the fact that they resonate firmly with a Western cultural stance. From the point of view of international mobility, the WA and SA graduate and professional competencies are clearly the main drivers and these must therefore be included in the drafting of the new education and training model.

The WSDA system, although certainly not the only internationally recognised system for course accreditation, comes across strongly as the dominant force in mutual recognition of engineering qualifications and professional registration and, in the context of this work, for BSE in particular. Significantly, EUR-ACE and other international agreements for accreditation systems across the world deal only with course accreditation and, for the most part, not professional competencies. The ideal of recognising and assessing professional competencies acquired in the workplace against a mutually agreed framework comes across clearly as a recognised strength of the EC and WSDA approaches, and therefore need these are the approaches considered in the concluding chapters of this work.

The range of opinions and views about the CIBSE concurs with much of the literature, suggesting that the CIBSE has structures and systems for course accreditation and engineer registration about which the BSE industry can be generally confident. The support of the CIBSE for company training schemes was remarked upon as being a particularly useful practice.

The CIBSE appears well placed to represent the industry in education and training matters and its guidance concerning course design, notwithstanding the breadth of BSE curriculum that it recommends, is generally believed to be well considered and fit for purpose. The wide range of subjects that should be taught in a BSE degree when factored against the requirements for a fundamental engineering skillset must, however, be acknowledged as a real problem for course design. In simple terms, there is not enough space in course structures to fit everything that might be considered necessary. This point has been considered in the development and synthesis of the new education and training model proposed in Chapter 5.

Chapter 5 – Development and Synthesis of an Education and training Model

5.1 Towards an internationalist model

Clearly there is much that the UK does concerning the education and training of BSEs that is well regarded, and as the previous chapter indicates, UK trained engineers working at more senior level appear to be generally well respected abroad, though more junior engineers, despite generally being very occupationally competent, often require some cultural stabilisation. A model has been constructed which attempts to build on the strengths identified in the UK training regime and address the weaknesses, such that engineers progressing through the model would be in a stronger position when applying for positions overseas, and once there, would be occupationally and culturally competent in a shorter timeframe. It is considered that the WSDA agreements for the international mutual recognition of engineering competencies are playing a positive role in encouraging sustainable development in the developing world, and thus, a model which satisfies the WA and SA standards could play a very real part in the drive towards this goal.

A key point emerging from the previous chapter about what makes UK BSEs so well regarded overseas, is that workplace training and the acquisition of professional competencies alongside university education is seen as a real strength, notwithstanding the point that much of the work based learning can often be unstructured. The interviews in particular established that what appears to give UK trained and professionally registered BSEs a competitive edge over those trained in many other parts of the world is the EC's insistence on practical competencies being demonstrated as a requirement of registration. The new education and training model therefore acknowledges this and proposes a complementary structured workplace training course alongside an appropriate degree programme, thus incorporating the acquisition of the professional competencies in conjunction with academic learning.

Attempts have also been made in the synthesis of the model to address any negative perception and issues emerging from the data analysis. The following points constitute the main guidance for the development of an efficient education and training model that could benefit trainees and employers, both at home and abroad:

- As a general principle the new education and training model is the amalgamation of a degree course meeting AHEP 3 standards with a practical workplace training scheme which allows trainees to demonstrate the PECs laid down in the UK-SPEC. To address the desire to make the model internationally recognisable it is proposed that the degree course should also be designed to meet WA and SA graduate standards, while the workplace training scheme should meet WA and SA professional standards.

- The model should allow for an appropriate degree course to run concurrently with properly structured, monitored and assessed workplace training in professional practice. Such a workplace training scheme could utilise the model of the CIBSE accredited training schemes which have been developed by some of the larger BSE employers. Workplace training scheme guidance is published by the CIBSE (CIBSE, 2014). Generally such schemes involve the use of a log book where trainees log their experiences and cross-reference these against the UK-SPEC competencies, and this process is monitored by in-company training mentors. This approach will work best when trainees attend university on a part-time basis alongside full-time employment, but full-time university attendees could be required, as an integral part of their programme, to undertake a structured work placement year to begin the assimilation of practical competencies. Both attendance modes would require work based learning to continue after completion of academic studies and graduation.

- The model should encompass a coherent, though flexible time frame such that BSEs may qualify within a known timescale. This should not necessarily attempt to speed up the process of qualification and registration, but should allow for engineers to work towards targets at each stage of their training.

- The model should allow, as much as possible within the confines of the present EC and WA/SA definitions, for due status and recognition to be afforded to both Incorporated and Chartered Engineers.

- It has been established in the preceding work that there is nothing inherently at fault with the UK-SPEC and WA/SA competencies, and these can be (and indeed often are) customised and interpreted pragmatically according to different engineering specialisms. To satisfy the wish for internationalism the model must address the WA/SA graduate and professional competencies, as well as the standards set out in AHEP 3 and the UK-SPEC. The literature and the thematic analysis of the interview data indicates that the EC and WA/SA approaches are the most suitable for UK graduates due to their wide international recognition, and engineers having been trained under these systems are likely to have the best skillset for working in most world locations.

- The underpinning fundamental engineering educational requirements must be satisfied by careful planning of the degree programme. Academic course content needs to be arranged such that the delivery of the fundamental skillset of mathematics and engineering principles is balanced appropriately with the specialist BSE applications.

- In light of advice from several interviewees and when taking account of overseas practice, it would seem prudent to include an introduction to the use of BSE industry standard software early in the university course as part of the overall foundation skillset. Such skills could be reinforced and applied in workplace training.

- The breadth of curriculum for BSE remains an issue, but this can be offset by careful planning of the curriculum in tandem with a properly structured work based learning programme, such that students gain a sufficient grounding in the most commonly encountered specialist areas. Students wishing to examine other highly specialist topic areas can be provided with the opportunity to do so in research projects in the later stages of their degree programme.

- The cultural discomfiture of the UK-SPEC and WA/SA standards having been written from a Western viewpoint could be addressed by the careful design of the academic part of the programme. The so-called softer engineering skills of management, leadership, commerce and business, could be given a more international flavour and it is proposed that these be allied with a study of engineering ethics and ethical behaviour, again with an international overview. Such studies could inform students of how ethical behaviour may be interpreted differently in various world locations, and about alternative world views on subjects such as sustainability, examining how these fit into the various cultural norms found around the world. Engineering ethics could also be further reinforced in the workplace training programme.

- The model could allow for the possibility of one year of the structured training to take place overseas. This is probably the most difficult part of the model to put into practice, however, but the structure of the model could facilitate such an ideal as an optional aspect.

Whilst not absolutely defining what should be taught and how it should be taught, the model attempts to steer towards a notion of an exemplar academic programme, allied with a structured work based training programme. Other issues identified during the preceding commentary have been addressed as they arise in the description of the model.

5.2 Content of the model

5.2.1 Academic content

As stated above, academic content has been designed to address the standards set in AHEP 3 and the WA and SA, whilst taking into account guidance from *The CIBSE Training and Development Manual* (CIBSE, 2014), as well as those issues raised in the data collection and analysis.

The proposed academic programme is to comprise largely of the content from existing programmes as discussed in Section 2.6.3, as this arrangement was found to be largely satisfactory and fit for purpose, though several refinements have been made to address issues raised. The academic programme consists of four main themes, which progress incrementally through the educational levels, as shown in Table 18 below.

Table 18 Thematic progression through NQF levels for BSE educational programme

Theme	Level 4 content	Level 5 content	Level 6 content	Level 7 content
1. Basic engineering skillset	• Mathematics • Engineering science • Engineering principles • Introduction to environmental analysis • Introduction to CAD and industry standard software	• Applied mathematics • Applied engineering science and principles • Use of industry standard software in systems design	• Environmental analysis (incl. use of software tools) • Use of industry standard software and engineering concepts in systems design	• Use of software tools and engineering concepts in major project work
2. Applied BSE	• Introduction to building services systems • Introductory design project using manual calculation methods	• Mechanical building services • Electrical building services • Integrated design project	• Sustainable technologies and sustainable design of services • Integrated design project	• Control engineering • Major research and design project
3. Research and academia	• Introduction to academic study skills	• Research methods	• Research project (dissertation)	
4. Associated industry studies	• Construction technology	• Management principles • Legal aspects • Engineering ethics and international cultural studies	• Finance and commerce • Engineering management	• Energy and environmental management • Sustainable design

This table self-evidently does not show the subject matter as discrete modules, and there is quite naturally some overlap between the main themes and the various subjects to be taught. The full detail of the model is discussed and shown in a number of diagrams and tables in Section 5.3.

The new educational programme allows for the fundamental mathematics, science and engineering skills to be taught at the lower educational level (NQF level 4) alongside an introduction to the use of industry standard software applications. Such learning should be extended and reinforced throughout the course, but the syllabus encourages students to apply such knowledge and skills in the design of energy efficient and sustainable systems for buildings from level 5 onwards.

It is proposed that the non-engineering skills and knowledge associated with the BSE industry be taught on a systematic and incremental basis throughout the duration of the course, starting with construction technology at level 4 and progressing through to project and personnel management, law, commerce and finance. Engineering ethics and international cultural studies is also introduced in this theme to address the earlier discussions concerning cultural differences and discomfiture.

Since many students enter BSE courses with non-standard qualifications such as HNCs, it is proposed that academic study skills are introduced at level 4 as an introduction and survival skillset, and this theme would progress to instruction in appropriate research methods at level 5, a self-driven research project (dissertation) in included at level 6, and a major research and design project at level 7, thus linking the design and academic themes.

The design theme is introduced early at level 4, with students being instructed in the basics of building services systems and being required to apply these to non-complex buildings. Although industry standard design software is to be introduced at level 4, it is suggested that students be encouraged to utilise hand calculation methods at this stage of their education. This ensures that when they do use industry standard calculation and design tools later in their education (and in professional practice) that they understand the design processes and are able to recognise the accuracy and veracity of solutions that software programmes provide. The design theme progresses incrementally through the programme and links design skills to research skills in a major project at level 7. Students should be provided with opportunities to work in multi-disciplinary groups in projects so that team working and leadership skills may be developed and practiced.

To provide students with an overall flavour of the various BSE sub disciplines, the specialist areas proposed as a minimum are as follows:

- Public Health – water, sanitation and waste systems, including water recycling and rainwater harvesting.
- Mechanical services – heating, ventilation and air conditioning (HVAC) systems to create safe and comfortable environments, including renewable technologies and energy efficient design solutions.
- Electrical Power – distribution, including connections to the public supply network, generation including renewable technologies, combined heat and power (CHP) and emergency generation.
- Lighting – electric lighting systems, including use and control of daylight.
- Control – lighting, current and building management systems, fire detection, CCTV, entertainment systems, security, telecoms and data communication systems and control systems.

These should be taught in an integrated and systematic way such that students do not see particular building services systems in isolation from others.

5.2.2 Work based learning

It is recognised that it is far more difficult in most cases to structure a work based learning programme than an academic programme, since, particularly for SMEs, commercial and operational factors may mean that the nature of work available for trainees cannot always be assured and may be subject to change. As previously mentioned, the CIBSE has published guidance about in-company training schemes in *The CIBSE Training and Development Manual* for the benefit of trainees and employers (CIBSE, 2014). This document is very detailed in its explanations of how trainees may acquire and demonstrate professional competencies and how workplace training mentors can assist trainees in this process, but it does not set out to prescribe any list of activities or anything of this sort. It is eminently more sensible to expect that companies will design their own training course to sit within the overall guidance that the CIBSE provides. Trainees are encouraged by the guidance document to maintain a log book detailing all professional activities in which they participate, to reflect upon these, and ultimately to cite where they have demonstrated each of the PECs.

This proposed model aims, as much as possible, to ally the in-company training course with the university programme, reinforcing the various skills and knowledge as they are acquired. However, the fluctuating nature of work available must be accepted and recognised, so a flexible thematic training course is proposed such that companies can adapt this to fit their own work patterns. The main themes identified are as shown below, and it is envisaged that trainees would progress incrementally to greater levels of responsibility according to each theme as their training programme continues:

Theme 1 – General practical and technical duties

This would involve in the first instance working in a junior capacity within a team, providing administrative assistance and support to more senior colleagues. As the trainee progresses the trainees may be given greater levels of autonomy and responsibility, culminating in supervised and, eventually, non-supervised team leadership roles.

Theme 2 – Engineering practice

This theme introduces the trainee to design work. In the first stages, trainees would be required to undertake design tasks such as carrying out calculations and producing working drawings under close supervision. As trainees progress they would be afforded more autonomy and may be given individual responsibility for sections of design work, which would necessarily be closely supervised at the earlier stages of training. The culmination of this theme would involve the trainee being responsible for a full design and providing technical leadership.

Theme 3 – Project management

This theme enables trainees to incrementally gain the skills needed to manage projects and deliver work to commercially set deadlines. Initially the trainees would be expected to observe and monitor the way that projects operate and are managed by their company. They would progress to being given sections of projects to look after under supervision, progressing eventually to having responsibility and accountability to individually manage projects and see these through to completion and delivery.

The way in which these themes relate to the PECs listed in the UK-SPEC, and to the WA and SA professional competencies, and the way in which these are allied with the educational programme is discussed and shown in various tables and figures in Section 5.3.

5.3 Structure of the proposed education and training model

The new model consists of an eight year structure with the aim of taking trainees through to IEng registration in seven years or CEng registration in eight years. All trainees are on a common pathway at the beginning of the programme and they are able to make a choice as to whether they aim for CEng or IEng at various stages in their training.

There are two interdependent parts to the model, which can be designed to work in harmony: university attendance to enable trainees to achieve the necessary educational requirement for engineer registration, and work based learning to enable trainees to acquire the competencies which go to make up the professional requirement for registration. The semi-structured interviews suggested strongly that the occupational competence of UK BSEs at a comparatively young age is seen as something very positive among engineers working overseas, and this is due in large part to the incidental (though often unstructured) work based learning that takes place alongside part-time college and university attendance, which is a common theme for BSE trainees in the UK. The proposed model therefore seeks to build upon this and formalise the work based learning aspect.

As there are part-time and full-time modes of university attendance in evidence at present, the model allows for either. In part-time university attendance mode, the trainee attends university on one day per week and works for an employer for the remainder of the week. A structured work based learning plan enables the trainee to begin acquiring the professional competencies that they would need for eventual engineer registration. For trainees aspiring to CEng registration a Masters degree is required. Some universities offer this as an integrated undergraduate MEng course, whereas others offer a BEng (Hons) plus a specialist free standing post-graduate MSc. The model has been adapted to incorporate both options.

In full-time university attendance mode, the educational requirements will obviously be met sooner in the process, but this comes without the benefit of concurrent workplace learning. Consequently a sandwich work placement year is incorporated in the third year of the programme to enable students to contextualise their academic knowledge and build upon this in their remaining year(s) of study. A fourth year of full-time study completes the BEng (Hons) (or a BEng without honours can be claimed as an alternative exit award by those not completing the full complement of learning) for those aiming for IEng registration. For trainees aiming for CEng registration a fifth year completes the MEng qualification. Alternatively, where a local MEng course is not available, trainees could progress from their BEng (Hons) onto a part-time specialist MSc degree.

Two to three years post qualification work based learning are then specified to complete the professional competencies to IEng or CEng. The seven/eight year attendance and work based learning programmes are summarised for part-time and full-time university attendance in the following Section 5.3.1.

5.3.1 Overall structure of the proposed model

Table 19 Summary of eight year education and training model with part-time university attendance

	IEng aim		**CEng aim**	
Year 1	University attendance + Work based learning		University attendance + Work based learning	
Year 2	University attendance + Work based learning		University attendance + Work based learning	
Year 3	University attendance + Work based learning		University attendance + Work based learning	
Year 4	University attendance + Work based learning	Possible to leave university with alt. exit award BEng (no honours) (IEng req. only)	University attendance + Work based learning	
Year 5	(University attendance) + Work based learning	Leave university with BEng (Hons) (Full IEng req. & part CEng req.)	University attendance + Work based learning	<u>Either:</u> leave university with BEng (Hons) (partial CEng req.) and progress to MSc course <u>Or:</u> continue with studies on MEng course
Year 6	Work based learning		University attendance (MEng or MSc) + work based learning	Leave university with MEng (Full CEng req.)
Year 7	Work based learning	Achievement of IEng professional req.	University attendance (MSc) + Work based learning	Leave university with MSc (Full CEng req.)
Year 8			Work based learning	Achievement of CEng professional req.

Table 20 Summary of eight year education and training model with full-time university attendance

<table>
<tr><th colspan="3">IEng aim</th><th colspan="2">CEng aim</th></tr>
<tr><td>Year 1</td><td colspan="2">University attendance</td><td colspan="2">University attendance</td></tr>
<tr><td>Year 2</td><td colspan="2">University attendance</td><td colspan="2">University attendance</td></tr>
<tr><td>Year 3</td><td colspan="2">Work based learning</td><td colspan="2">Work based learning</td></tr>
<tr><td rowspan="2">Year 4</td><td rowspan="2">University attendance</td><td>Possible to leave university with alt. exit award BEng (no honours)
(IEng req. only)</td><td rowspan="2">University attendance</td><td rowspan="2"><u>Either:</u> leave university with BEng (Hons) (partial CEng req.) and progress to MSc course
<u>Or:</u> continue with studies on MEng course</td></tr>
<tr><td>Leave university with BEng (Hons)
(Full IEng req. & part CEng req.)</td></tr>
<tr><td>Year 5</td><td colspan="2">Work based learning</td><td>University attendance (MEng)
University Attendance (MSc) + work based learning</td><td>Leave university with MEng
(Full CEng req.)</td></tr>
<tr><td>Year 6</td><td colspan="2">Work based learning</td><td>University Attendance (MSc) + work based learning</td><td>Leave university with MSc
(Full CEng req.)</td></tr>
<tr><td>Year 7</td><td>Work based learning</td><td>Achievement of IEng professional req.</td><td colspan="2">Work based learning</td></tr>
<tr><td>Year 8</td><td colspan="2"></td><td>Work based learning</td><td>Achievement of CEng professional req.</td></tr>
</table>

Although an eight year structure is shown, it is suggested that this need not necessarily be rigid (apart from the university attendance which must abide by regulations and requirements of the HEIs concerned) and candidates who are able to demonstrate the professional competencies earlier should be allowed to make their application for registration. Alternatively, those candidates who are not ready for CEng or IEng registration after the stipulated period, should not be deemed to have failed the programme and can be provided with as much time as necessary after completion of their academic course.

A more detailed description of the structure of the proposed model and where the various graduate and professional standards are satisfied is provided in the following Section 5.3.2.

5.3.2 Detailed structure of the new model

The flowcharts below show overviews of the proposed model linking attendance on an accredited degree programme to achieve the educational requirement for registration alongside complementary work based learning which facilitates working towards the professional requirement. Figure 25 shows university part-time attendance alongside full-time employment in industry, while Figure 26 shows a full-time university attendance model where the work based learning is delivered in part during the sandwich year of the degree programme and the rest of the professional experience occurs post-graduation.

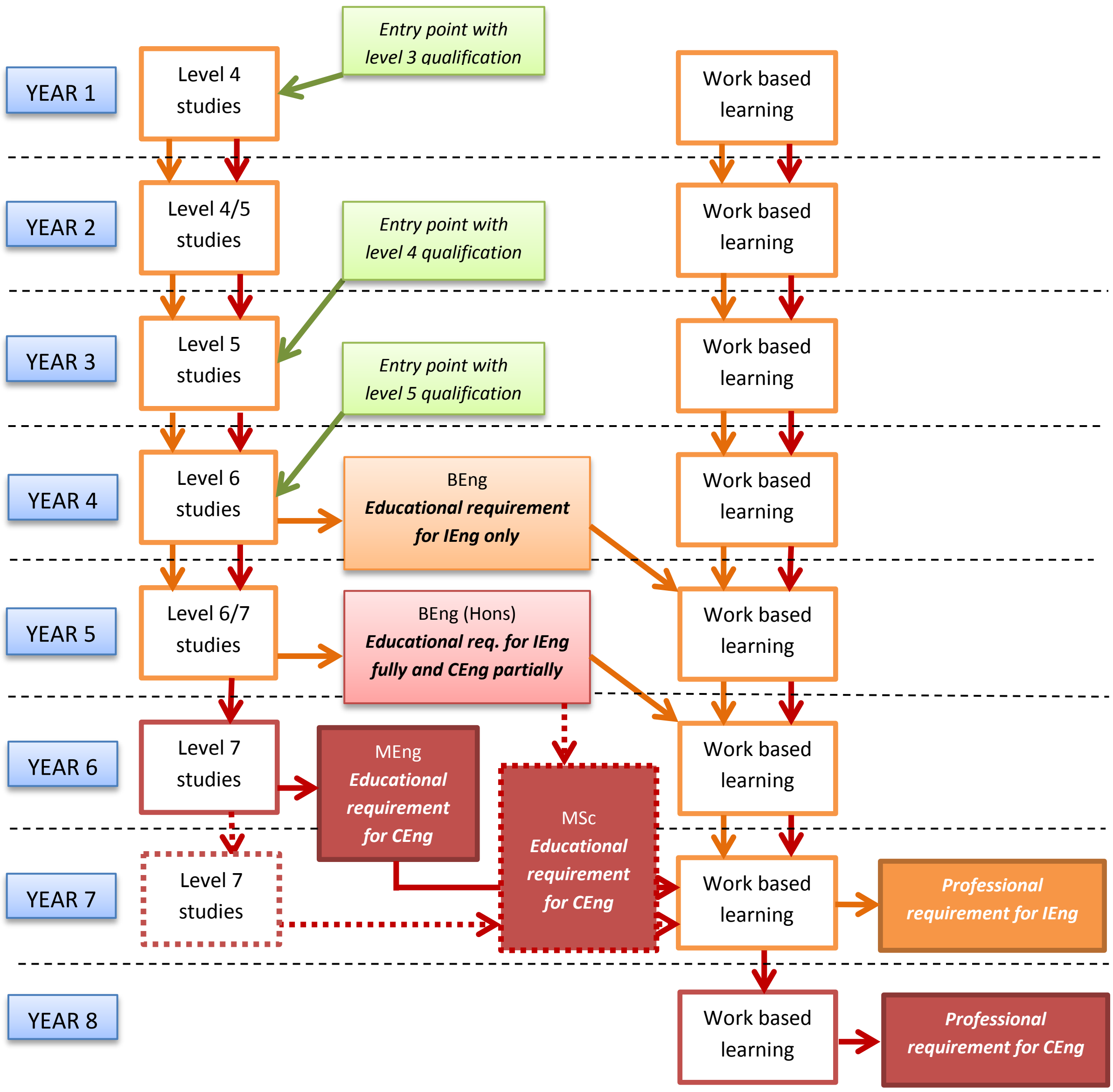

Figure 25 Proposed education and training model with part-time university attendance

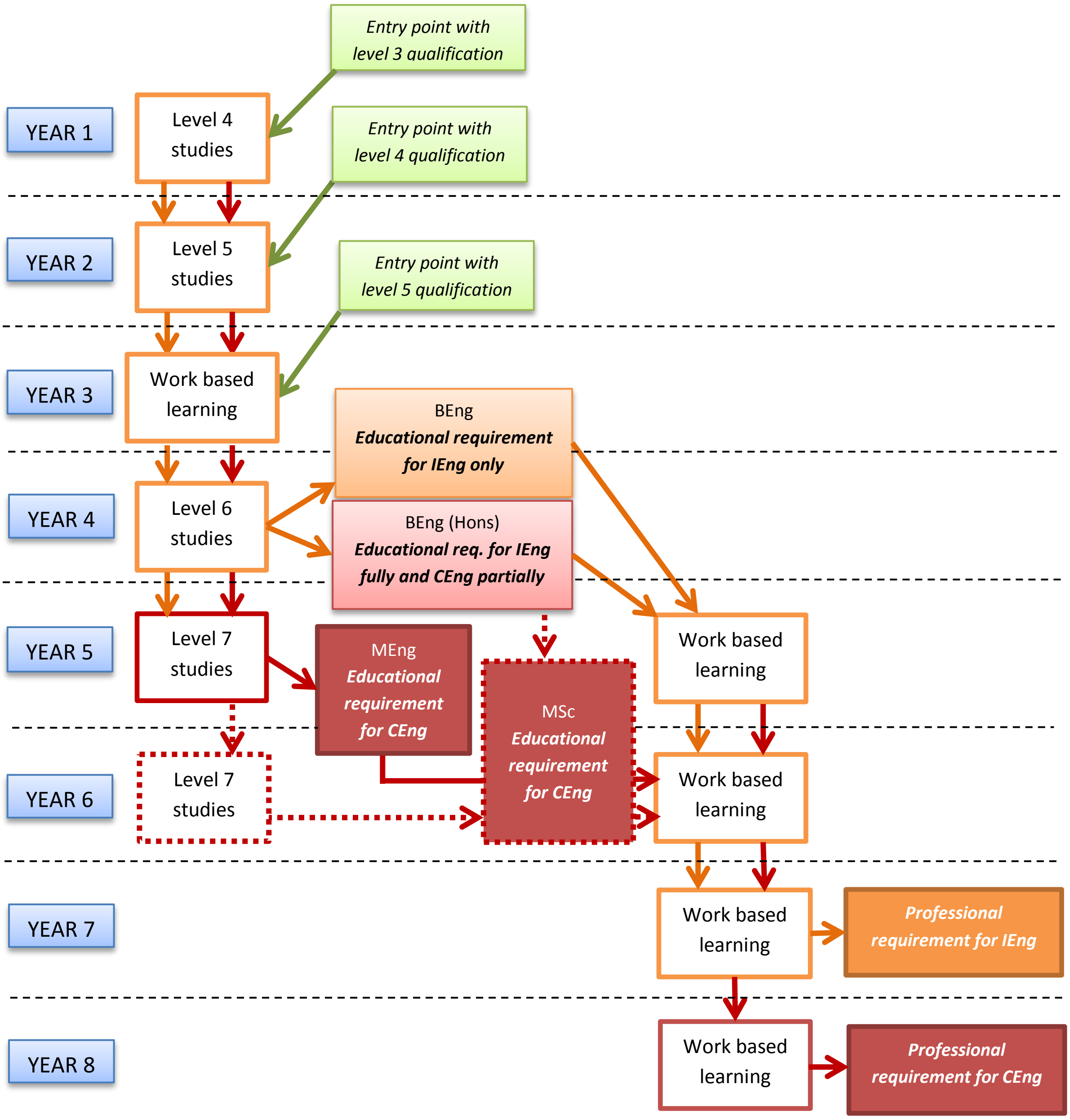

Figure 26 Proposed education and training model with full-time university attendance

The tables below show more of the detail relating to the proposed training programme, including where the AHEP 3, UK-SPEC, WA and SA standards are achieved, and these should be read in conjunction with the flowcharts. Table 21 shows the part-time university attendance model, while Table 22 shows the full-time attendance model. The designatory codes shown in the tables relating to the UK-SPEC, AHEP 3, WA and SA standards are taken directly from Appendices 1, 2 and 3.

Table 21 Detail of proposed education and training model with part-time university attendance

YEAR 1

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	**IEng**	**WA**	**SA**		**CEng**	**IEng**	**WA**	**SA**
4	10	Academic Study Skills	D6 P4 G1, G2, G3	D6 P4i G1, G2, G3	WA10, WA12	SA10, SA12	General practical and technical duties: working as part of a team	D1, D3	D1, D3	WA9, WA10	SA9, SA10
4	20	Construction Technology	SM1b, SM6m D1 P1, P2	SM1i D1i P1i, P2i	WA7	SA7	Engineering practice: supervised assistance with design or practical tasks	A1	A1	WA1	SA1
4	20	Mathematics	SM2b	SM2i	WA1	SA1					
4	30	Design Project 1	D1, D6 EL1, EL2, EL3 P1, P2, P3, P4, P6, P8 G1, G2, G3	D1i, D6 EL1, EL2, EL3i P1i, P2i, P3i, P4i, P6i G1, G2, G3	WA1, WA3, WA7, WA10	SA1, SA3, SA7, SA10	Project management: supervised monitoring of projects	C1	C1	WA11	SA11

YEAR 2

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	**IEng**	**WA**	**SA**		**CEng**	**IEng**	**WA**	**SA**
4	20	Engineering Science	SM1b, SM2b, SM6m P2, P3	SM1i, SM2i P2i, P3i	WA1, WA2	SA1, SA2	General practical and technical duties: working as part of a team with increasing responsibilities	D1, D3	D1, D3	WA9, WA10	SA9, SA10
4	20	Engineering Principles	SM1b, SM2b EA1b, EA2 P2, P3	SM1i, SM2i EA1i, EA2i P2, P3	WA1, WA2	SA1, SA2					
5	20	Mechanical Services	SM1b, SM3m, SM4m EA1b D1, D3 EL1, EL2, EL4 P1, P2, P3, P4, P6, P8	SM1i EA1i D1i, D3 EL1, EL2, EL4 P1i, P2i, P3i, P4i, P6i	WA1, WA2, WA3, WA5, WA7	SA1, SA2, SA3, SA5, SA7	Engineering practice: supervised design or practical tasks	A1, A2 E1	A1, A2 E1	WA1	SA1
5	20	Electrical Services	SM1b, SM3m, SM4m EA1b D1, D3 EL1, EL2, EL4 P1, P2, P3, P4, P6, P8	SM1i EA1i D1i, D3 EL1, EL2, EL4 P1i, P2i, P3i, P4i, P6i	WA1, WA2, WA3, WA5, WA7	SA1, SA2, SA3, SA5, SA7	Project management: monitoring of projects	C1, C2	C1, C2	WA11	SA11

YEAR 3

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
5	10	Mathematics	SM2b, SM6m	SM2i	WA1, WA2	SA1, SA2	General practical and technical duties: working as part of a team with more substantial responsibility	D1, D2, D3	D1, D2, D3	WA9, WA10	SA9, SA10
5	30	Design Project 2	SM4m, SM6m EA3b, EA4b D1, D2, D3, D6 EL2, EL3, EL4 P1, P2, P3, P4, P5, P6, P7, P8, P10m, P11 G1, G2, G3	EA3i, EA4i D1i, D2i, D3, D6 EL2, EL3i, EL4 P1i, P2i, P3i, P4i, P6i, P7, P11i G1, G2, G3	WA1, WA2, WA3, WA4, WA5, WA6, WA7, WA10, WA11	SA1, SA2, SA3, SA4, SA5, SA6, SA7, SA10, SA11					
5	20	Engineering Management	D1, D2 EL1, EL2, EL3, EL4, EL5, EL6 P1, P5, P6, P7, P11	D1i, D2i EL1, EL2, EL3i, EL4, EL5, EL6i P1i, P6i, P7, P11i	WA6, WA7, WA8, WA11	SA6, SA7, SA8, SA11	Engineering practice: working independently with minimal supervision on design or practical tasks	A1, A2 B1, B3 E1, E3	A1, A2 B1, B3 E1, E3	WA1, WA2, WA3, WA5	SA1, SA2, SA3, SA5
5	20	Engineering Ethics and Cultural Studies	D1 EL1m, EL2, EL4, EL5m, EL6, EL7m P1, P5, P6, P7, P11	D1i EL1, EL2, EL4, EL5, EL6i P1i, P6i, P7, P11i	WA6, WA7, WA8, WA12	SA6, SA7, SA8, SA12	Project management: supervised responsibility for project delivery	C1, C2 E1, E2	C1, C2 E1, E2	WA6, WA11	SA6, SA11

YEAR 4

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
6	20	Engineering Management	D1, D2, D4, D5 EL1m, EL2, EL3m, EL4, EL5m, EL6m, EL7m P1, P5, P6, P7, P9m, P10m, P11m	D1i, D2i, D4i, D5 EL1, EL2, EL3i, EL4, EL5, EL6i P1i, P6i, P7, P11i	WA6, WA7, WA8, WA11, WA12	SA6, SA7, SA8, SA11, SA12	General practical and technical duties: working as part of a team with supervised leadership roles	A2 B1, B2 C1, C2, C3 D1, D2, D3	A2 B1, B2 C1, C2, C3 D1, D2, D3	WA8, WA9, WA10	SA8, SA9, SA10
6	20	Design Project 3	SM4m, SM5m, SM6m EA3b, EA4m, EA5m, EA6m D1, D2, D3m, D4, D5, D6 EL2, EL3m, EL4, EL7m P1, P2m, P3, P4, P5, P6, P7, P8, P9m, P10m, P11m G1, G2, G3m, G4	EA3i, EA4i D1i, D2i, D3, D4i, D5, D6 EL2, EL3i, EL4 P1i, P2i, P3i, P4i, P6i, P7, P11i G1, G2, G3, G4	WA1, WA2, WA3, WA4, WA5, WA6, WA7, WA8, WA9, WA10, WA11	SA1, SA2, SA3, SA4, SA5, SA6, SA7, SA8, SA9, SA10, SA11	Engineering practice: undertaking design or practical tasks unsupervised	A1, A2 B1, B2, B3 E1, E3	A1, A2 B1, B2, B3 E1, E3	WA1, WA2, WA3, WA5, WA6	SA1, SA2, SA3, SA5, SA6
6	20	Energy & Sustainability	SM1m, SM2m, SM3m, SM4m, SM6m EA1m, EA2, EA5m EL2, EL4 P1, P2m	SM1i, SM2i EA1i, EA2i EL2, EL4 P1i, P2i	WA1, WA2, WA3, WA6, WA7	SA1, SA2, SA3, SA6, SA7	Project management: responsibility for project management through to delivery	C1, C2, C3 E1, E2	C1, C2, C3 E1, E2	WA6, WA11	SA6, SA11

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
6	20	Environmental Analysis	SM2b, SM1m, SM3m, SM4m, SM5m, SM6m EA1m, EA2, EA3m, EA6m P1, P2m	SM2b, SM1m, SM3m, SM4m, SM5m, SM6m EA1m, EA2, EA3m, EA6m P1, P2m	WA1, WA2, WA3, WA4, WA5, WA7	SA1, SA2, SA3, SA4, SA5, SA7					
Possible university exit point		120 credits at level 4 120 credits at level 4 60 credits (min.) at level 6	**BEng** Alternative exit award assumes 20 level 6 credits not attempted or failed. **Full educational requirement for IEng only**								

YEAR 5

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
6	40	Research Project	P1, P3 G1, G2, G3m	P1i, P3i G1, G2, G3	WA10, WA11, WA12	SA10, SA11, SA12	General practical and technical duties: working as part of a team with leadership roles	A2 B1, B2 C1, C2, C3 D1, D2, D3	A2 B1, B2 C1, C2, C3 D1, D2, D3	WA8, WA9, WA10, WA12	SA8, SA9, SA10, SA12
7	20	Energy & Environmental Management	SM1m, SM3m, SM4m, SM6m EA1m, EA2, EA5m, EA6m EL2, EL4 P1, P2m, P9m		WA1, WA2, WA6, WA7, WA11		Engineering practice: undertaking complete design or practical projects unsupervised	A1, A2 B1, B2, B3 E1, E3	A1, A2 B1, B2, B3 E1, E3	WA1, WA2, WA3, WA5, WA6, WA7	SA1, SA2, SA3, SA5, SA6, SA7
7	20	Control Engineering for Buildings	SM1m, SM2m, SM3m, SM4m EA1m, EA2, EA5m, EA6m EL2, EL4, EL7m P1, P2m, P9m		WA1, WA2, WA3, WA5, WA7		Project management: responsibility for project management through to delivery	C1, C2, C3 E1, E2	C1, C2, C3 E1, E2	WA6, WA11	SA6, SA11
Possible university exit point		120 credits at level 4 120 credits at level 4 120 credits at level 6	**BEng (Hons)** Target qualification assumes all level 6 credits achieved; Alternative exit award assumes 40 level 7 credits not attempted or failed. **Full educational requirement for IEng** **Partial educational requirement for CEng**								

YEAR 6

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
7	60	Design & Research Project	SM1m, SM2m, SM3m, SM4m, SM5m, SM6m EA2, EA3m, EA4m, EA5m, EA6m D1, D2, D3m, D4, D5, D6, D7m, D8m EL1m, EL2, EL3m, EL4, EL5m, EL6m, EL7m P1, P2, P3, P4, P5, P6, P7, P8, P9m, P10m, P11m G1, G2, G3m, G4	…………….	WA1, WA2, WA3, WA4, WA5, WA6, WA7, WA8, WA9, WA10, WA11, WA12	…………….	General practical and technical duties: working as part of a team with significant leadership roles	A2 B1, B2 C1, C2, C3 D1, D2, D3	A2 B1, B2 C1, C2, C3 D1, D2, D3	WA4, WA8, WA9, WA10, WA12	SA4, SA8, SA9, SA10, SA12
							Engineering practice: undertaking complete design or practical projects unsupervised	A1, A2 B1, B2, B3 E1, E3	A1, A2 B1, B2, B3 E1, E3	WA1, WA2, WA3, WA4, WA5, WA6, WA7	SA1, SA2, SA3, SA4, SA5, SA6, SA7
7	20	Facilities Management	SM3m, SM6m EA5m, EA6m D1, D2 EL3m, EL5m, EL7m P1, P2, P4, P9m, P10m	…………….	WA1, WA2, WA6, WA7, WA11	…………….	Project management: responsibility for project management through to delivery	C1, C2, C3 E1, E2	C1, C2, C3 E1, E2	WA6, WA11	SA6, SA11

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
Conclusion of academic studies 480 credits total		120 credits at level 4 120 credits at level 4 120 credits at level 6 120 credits at level 7	**MEng** **Full educational requirement for CEng**								

YEAR 7

NQF level	**Credit value**	**Module title**	**AHEP 3 standards addressed**		**WA & SA graduate standards addressed**		**Professional learning in workplace**	**UK-SPEC standards addressed**		**WA & SA professional standards addressed**	
			CEng	**IEng**	**WA**	**SA**		**CEng**	**IEng**	**WA**	**SA**
							General practical and technical duties: working as part of a team with leadership roles	A2 B1, B2 C1, C2, C3 D1, D2, D3	A2 B1, B2 C1, C2, C3 D1, D2, D3 E4	WA4, WA8, WA9, WA10, WA12	SA4, SA8, SA9, SA10, SA12
							Engineering practice: undertaking complete design or practical projects unsupervised	A1, A2 B1, B2, B3 E1, E3	A1, A2 B1, B2, B3 E1, E3	WA1, WA2, WA3, WA4, WA5, WA6, WA7	SA1, SA2, SA3, SA4, SA5, SA6, SA7
							Project management: responsibility for project management through to delivery	C1, C2, C3, C4 E1, E2	C1, C2, C3, C4 E1, E2	WA6, WA11	SA6, SA11
IEng application											

YEAR 8

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
							General practical and technical duties: working as part of a team with leadership roles	A2 B1, B2, B3 C1, C2, C3 D1, D2, D3 E4	…………….	WA4, WA8, WA9, WA10, WA12	…………….
							Engineering practice: responsibility for undertaking design projects unsupervised	A1, A2 B1, B2, B3 E1, E3	…………….	WA1, WA2, WA3, WA4, WA5, WA6, WA7	…………….
							Project management: responsibility for project management through to delivery	C1, C2, C3, C4 E1, E2, E3	…………….	WA6, WA11	…………….
CEng application											

Table 22 Detail of proposed education and training model with full-time university attendance

YEAR 1 – University attendance

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
4	10	Academic Study Skills	D6 P4 G1, G2, G3	D6 P4i G1, G2, G3	WA10, WA12	SA10, SA12					
4	20	Construction Technology	SM1b, SM6m D1 P1, P2	SM1i D1i P1i, P2i	WA7	SA7					
4	20	Mathematics	SM2b	SM2i	WA1	SA1					
4	30	Design Project 1	D1, D6 EL1, EL2, EL3 P1, P2, P3, P4, P6, P8 G1, G2, G3	D1i, D6 EL1, EL2, EL3i P1i, P2i, P3i, P4i, P6i G1, G2, G3	WA1, WA3, WA7, WA10	SA1, SA3, SA7, SA10					
4	20	Engineering Science	SM1b, SM2b, SM6m P2, P3	SM1i, SM2i P2i, P3i	WA1, WA2	SA1, SA2					
4	20	Engineering Principles	SM1b, SM2b EA1b, EA2 P2, P3	SM1i, SM2i EA1i, EA2i P2, P3	WA1, WA2	SA1, SA2					

YEAR 2 – University attendance

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
5	20	Mechanical Services	SM1b, SM3m, SM4m EA1b D1, D3 EL1, EL2, EL4 P1, P2, P3, P4, P6, P8	SM1i EA1i D1i, D3 EL1, EL2, EL4 P1i, P2i, P3i, P4i, P6i	WA1, WA2, WA3, WA5, WA7	SA1, SA2, SA3, SA5, SA7					
5	20	Electrical Services	SM1b, SM3m, SM4m EA1b D1, D3 EL1, EL2, EL4 P1, P2, P3, P4, P6, P8	SM1i EA1i D1i, D3 EL1, EL2, EL4 P1i, P2i, P3i, P4i, P6i	WA1, WA2, WA3, WA5, WA7	SA1, SA2, SA3, SA5, SA7					
5	10	Mathematics	SM2b, SM6m	SM2i	WA1, WA2	SA1, SA2					
5	30	Design Project 2	SM4m, SM6m EA3b, EA4b D1, D2, D3, D6 EL2, EL3, EL4 P1, P2, P3, P4, P5, P6, P7, P8, P10m, P11 G1, G2, G3	EA3i, EA4i D1i, D2i, D3, D6 EL2, EL3i, EL4 P1i, P2i, P3i, P4i, P6i, P7, P11i G1, G2, G3	WA1, WA2, WA3, WA4, WA5, WA6, WA7, WA10, WA11	SA1, SA2, SA3, SA4, SA5, SA6, SA7, SA10, SA11					
5	20	Engineering Management	D1, D2 EL1, EL2, EL3, EL4, EL5, EL6 P1, P5, P6, P7, P11	D1i, D2i EL1, EL2, EL3i, EL4, EL5, EL6i P1i, P6i, P7, P11i	WA6, WA7, WA8, WA11	SA6, SA7, SA8, SA11					
5	20	Engineering Ethics and Cultural Studies	D1 EL1m, EL2, EL4, EL5m, EL6, EL7m P1, P5, P6, P7, P11	D1i EL1, EL2, EL4, EL5, EL6i P1i, P6i, P7, P11i	WA6, WA7, WA8, WA12	SA6, SA7, SA8, SA12					

YEAR 3 – Work based learning

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
							General practical and technical duties: working as part of a team	D1, D3	D1, D3	WA9, WA10	SA9, SA10
							Engineering practice: supervised assistance with design or practical tasks	A1	A1	WA1	SA1
							Project management: supervised monitoring of projects	C1	C1	WA11	SA11

YEAR 4 – University attendance

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
6	20	Engineering Management	D1, D2, D4, D5 EL1m, EL2, EL3m, EL4, EL5m, EL6m, EL7m P1, P5, P6, P7, P9m, P10m, P11m	D1i, D2i, D4i, D5 EL1, EL2, EL3i, EL4, EL5, EL6i P1i, P6i, P7, P11i	WA6, WA7, WA8, WA11, WA12	SA6, SA7, SA8, SA11, SA12					
6	20	Design Project 3	SM4m, SM5m, SM6m EA3b, EA4m, EA5m, EA6m D1, D2, D3m, D4, D5, D6 EL2, EL3m, EL4, EL7m P1, P2m, P3, P4, P5, P6, P7, P8, P9m, P10m, P11m G1, G2, G3m, G4	EA3i, EA4i D1i, D2i, D3, D4i, D5, D6 EL2, EL3i, EL4 P1i, P2i, P3i, P4i, P6i, P7, P11i G1, G2, G3, G4	WA1, WA2, WA3, WA4, WA5, WA6, WA7, WA8, WA9, WA10, WA11	SA1, SA2, SA3, SA4, SA5, SA6, SA7, SA8, SA9, SA10, SA11					
6	20	Energy & Sustainability	SM1m, SM2m, SM3m, SM4m, SM6m EA1m, EA2, EA5m EL2, EL4 P1, P2m	SM1i, SM2i EA1i, EA2i EL2, EL4 P1i, P2i	WA1, WA2, WA3, WA6, WA7	SA1, SA2, SA3, SA6, SA7					
6	20	Environmental Analysis	SM2b, SM1m, SM3m, SM4m, SM5m, SM6m EA1m, EA2, EA3m, EA6m P1, P2m	SM2b, SM1m, SM3m, SM4m, SM5m, SM6m EA1m, EA2, EA3m, EA6m P1, P2m	WA1, WA2, WA3, WA4, WA5, WA7	SA1, SA2, SA3, SA4, SA5, SA7					
6	40	Research Project	P1, P3 G1, G2, G3m	P1i, P3i G1, G2, G3	WA10, WA11, WA12	SA10, SA11, SA12					

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
Possible university exit point		120 credits at level 4 120 credits at level 4 60 credits (min.) at level 6	**BEng** Alternative exit award assumes 40 level 6 credits not attempted. **Full educational requirement for IEng only**								
		120 credits at level 4 120 credits at level 4 120 credits at level 6	**BEng (Hons)** Target qualification assumes all level 6 modules passed; **Full educational requirement for IEng** **Partial educational requirement for CEng**								

YEAR 5 – University attendance

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
7	20	Energy & Environmental Management	SM1m, SM3m, SM4m, SM6m EA1m, EA2, EA5m, EA6m EL2, EL4 P1, P2m, P9m	....	WA1, WA2, WA6, WA7, WA11	....					
7	20	Control Engineering for Buildings	SM1m, SM2m, SM3m, SM4m EA1m, EA2, EA5m, EA6m EL2, EL4, EL7m P1, P2m, P9m	....	WA1, WA2, WA3, WA5, WA7	....					
7	60	Design & Research Project	SM1m, SM2m, SM3m, SM4m, SM5m, SM6m EA2, EA3m, EA4m, EA5m, EA6m D1, D2, D3m, D4, D5, D6, D7m, D8m EL1m, EL2, EL3m, EL4, EL5m, EL6m, EL7m P1, P2, P3, P4, P5, P6, P7, P8, P9m, P10m, P11m G1, G2, G3m, G4	....	WA1, WA2, WA3, WA4, WA5, WA6, WA7, WA8, WA9, WA10, WA11, WA12	....					
7	20	Facilities Management	SM3m, SM6m EA5m, EA6m D1, D2 EL3m, EL5m, EL7m P1, P2, P4, P9m, P10m	....	WA1, WA2, WA6, WA7, WA11	....					

<table>
<tr><th rowspan="2">NQF level</th><th rowspan="2">Credit value</th><th rowspan="2">Module title</th><th colspan="2">AHEP 3 standards addressed</th><th colspan="2">WA & SA graduate standards addressed</th><th rowspan="2">Professional learning in workplace</th><th colspan="2">UK-SPEC standards addressed</th><th colspan="2">WA & SA professional standards addressed</th></tr>
<tr><th>CEng</th><th>IEng</th><th>WA</th><th>SA</th><th>CEng</th><th>IEng</th><th>WA</th><th>SA</th></tr>
<tr><td colspan="2">Conclusion of academic studies</td><td>120 credits at level 4
120 credits at level 4
120 credits at level 6</td><td colspan="4">MEng
Full educational requirement for CEng</td><td colspan="5"></td></tr>
</table>

YEAR 6 – Work based learning

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
							General practical and technical duties: working as part of a team with significant leadership roles	A2 B1, B2 C1, C2, C3 D1, D2, D3	A2 B1, B2 C1, C2, C3 D1, D2, D3	WA4, WA8, WA9, WA10, WA12	SA4, SA8, SA9, SA10, SA12
							Engineering practice: undertaking complete design or practical projects unsupervised	A1, A2 B1, B2, B3 E1, E3	A1, A2 B1, B2, B3 E1, E3	WA1, WA2, WA3, WA4, WA5, WA6, WA7	SA1, SA2, SA3, SA4, SA5, SA6, SA7
							Project management: responsibility for project management through to delivery	C1, C2, C3 E1, E2	C1, C2, C3 E1, E2	WA6, WA11	SA6, SA11

YEAR 7 – Work based learning

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
							General practical and technical duties: working as part of a team with leadership roles	A2 B1, B2 C1, C2, C3 D1, D2, D3	A2 B1, B2 C1, C2, C3 D1, D2, D3 E4	WA4, WA8, WA9, WA10, WA12	SA4, SA8, SA9, SA10, SA12
							Engineering practice: undertaking complete design or practical projects unsupervised	A1, A2 B1, B2, B3 E1, E3	A1, A2 B1, B2, B3 E1, E3	WA1, WA2, WA3, WA4, WA5, WA6, WA7	SA1, SA2, SA3, SA4, SA5, SA6, SA7
							Project management: responsibility for project management through to delivery	C1, C2, C3, C4 E1, E2	C1, C2, C3, C4 E1, E2	WA6, WA11	SA6, SA11
IEng application											

YEAR 8 – Work based learning

NQF level	Credit value	Module title	AHEP 3 standards addressed		WA & SA graduate standards addressed		Professional learning in workplace	UK-SPEC standards addressed		WA & SA professional standards addressed	
			CEng	IEng	WA	SA		CEng	IEng	WA	SA
							General practical and technical duties: working as part of a team with leadership roles	A2 B1, B2, B3 C1, C2, C3 D1, D2, D3 E4	…………….	WA4, WA8, WA9, WA10, WA12	…………….
							Engineering practice: responsibility for undertaking design projects unsupervised	A1, A2 B1, B2, B3 E1, E3	…………….	WA1, WA2, WA3, WA4, WA5, WA6, WA7	…………….
							Project management: responsibility for project management through to delivery	C1, C2, C3, C4 E1, E2, E3	…………….	WA6, WA11	…………….
CEng application											

Chapter 6 – Initial Evaluations of the Proposed Education and Training Model

6.1 Concluding semi-structured interviews

A small and more focussed set of four semi-structured interviews (as described in Section 3.2.5) was arranged to address objective 10, to make some initial evaluations about the utility of the new education and training model, and also to revisit objective 9 where relevant and necessary. The questions used to structure the interviews are reproduced in Appendix 7.

Objective 9 *– Elicit views about what an education and training model should encompass to facilitate internationalism in BSE education.*

Objective 10 *– Synthesise and critically evaluate an education and training model to promote internationalism in BSE.*

Two respondents who had participated in the first set of interviews were selected again due to their excellent understanding of the research question, their level of interest in the project, and to ensure continuity in the final phase of the work, their detailed contributions to the previous interviews (Respondents 1 and 2). Two other interviewees were selected based upon recommendation of interviewees in the previous round of interviews (Respondents 3 and 4).

The respondents were therefore as follows:

- Two senior PEI staff members who have unique experience of working with the EC, WSDA and EUR-ACE accreditation systems (Respondents 1 and 2).
- Two members of university academic staff, currently practising in UK, though with substantial experience of working in overseas universities (Respondents 3 and 4).

A similar protocol was followed as for the previous interviews in that the participants were provided with similar information and documentation as previously, though they were also provided with a precis of the work completed thus far and details of the proposed education and training model, along with explanatory notes. The interviewees were given several days to read and consider the information provided before the interviews took place, and all interviews lasted around 30 minutes. The same interview approach was used as previously, a series of open questions relating to the specific objectives were asked using a conversational style, allowing the interviewees to volunteer as much information and opinion as possible. All respondents were also invited to make further comment by email should they so wish, and all expressed a wish to view and comment upon working drafts of the work, and a wish to read the final thesis.

The results from these interviews were again analysed thematically and summaries are given in the following table and in the successive commentary.

Table 23 Summary of responses to concluding semi-structured interviews

Question	Respondent 1	Respondent 2	Respondent 3	Respondent 4
What do you like about the model and what do you not like?	The model is concise and well ordered, showing very clear routes for progression. Eight years seems a long time to qualification, but this is comparable with current qualification timescales. I do like the idea of cross referencing the WA and SA competencies alongside the EC competencies.	The model includes all routes to IEng and CEng, however, I would ideally like to see more differentiation between IEng and CEng, though I know this would be very difficult to achieve with the BSE discipline.	The model differentiates between IEng and CEng registration aims, it takes account of MEng and MSc progression routes and there are recognisable goals along the way, so I believe it is well founded.	It is a good attempt at allying professional competencies picked up in work based learning with academic learning. I think referencing the WA and SA competencies throughout is a good idea and is likely to encourage students to focus on a career overseas.
How do you feel about the principle of work based learning running concurrently with higher education? Do you believe that the structure of the work based training course is correct and well-founded? Do you feel that this model could be workable for employers?	The overall principle is certainly correct. This is a good first attempt at a cohesive model, though a lot more development is needed here. Larger international employers would find this model more utilitarian than SMEs. It is hard to see how smaller companies could provide the range of workplace activities that might be specified in a rigid model. Degree apprenticeships seek to tackle some of the same issues as this model but of course there is no provision for internationalism or CEng qualification with DAs.	This is a well-founded idea, but I think more development is needed here. I can think of a number of other components that could be contained within the work based learning programme.* **These are detailed along with other suggestions in Section 6.1.3* Have you looked at allying your model with degree apprenticeship models? DAs only take student up to IEng though, which is disappointing.	From an academic point of view I think it is an excellent idea to provide a structured framework to sandwich placements and work based learning. The structure of this would need to be agreed with the major employers and professional body.	This looks like a good idea, but I think there is some way to go before the structure of the work based programme can be established. Does your model fit well with degree apprenticeships? This might be a way forward to acceptance of the new model.

Question	Respondent 1	Respondent 2	Respondent 3	Respondent 4
Do you believe the academic content of the model is correct and well-founded?	From the point of view of a non-academic person, the programme would appear to tick all the right boxes. From the point of view of a professional body representative, I like the idea of bringing in more content around the subject of engineering ethics.	The academic course looks comparable with courses of its type so I have no issue with it. I would be interested to see the detail of how the new modules proposed will provide a more international focus.	The main parts of the academic model are recognisable and there are one or two variations which provide an internationalist flavour. It seems a good idea to address international cultural issues and engineering ethics, though I would be careful about trying to fit even more content into a BSE degree programme.	The model appears to contain all the main components I would expect to see in a well-rounded BSE degree programme, and there are quite a few useful refinements.
How do you feel about the idea of a year of the training programme being delivered overseas?	It is a good idea and I know many universities are already building this into their degree programmes. I foresee problems encouraging smaller employers on board with this, however.	It is a good idea, but I think is should be advisory rather than compulsory. Many employers would struggle to accommodate this.	Many universities already offer this but as far as I know BSE students rarely take up such opportunities. Building this into an overall programme of study, where it is supported by an employer could encourage students to take advantage of this.	I like the idea of building in the possibility of a year spent abroad. If the obvious problems like getting agreement from employers could be solved, I'm sure this would help to attract young people into the industry and encourage engineers to seek overseas career development.
Do you believe that this model could improve international prospects for UK BSEs?	Undoubtedly it could. EC registration is supposed to address internationalism because the EC registration titles are recognised across much of the world, but this model takes things a stage further.	I'm not sure in the first instance that overseas employers would notice much difference in the quality of graduates, but I imagine that if such a model were widely used then word would spread.	This model is likely to focus students more on a career abroad and seeks to prepare them for this.	I think referencing the WA and SA competencies is likely to encourage students to focus on a career overseas. If engineering ethics and mutual cultural appreciation are properly taught, this could be very valuable to UK graduates.

Question	Respondent 1	Respondent 2	Respondent 3	Respondent 4
Do you believe that this model could be exported overseas?	In some locations, possibly. I don't think a model like this is likely to work everywhere because in many countries engineer registration often only depends upon academic qualifications only and workplace competencies are not measured.	I'm sure that this model could be adapted to overseas education and training practices, but I think it would be a sufficient enough challenge at present selling the model to industry in the UK.	I can see that this could happen if industry at home bought into the model. Education and training in many overseas locations is similar to the UK and there is no reason why this kind of model couldn't work.	This would depend on whether the model or something like it was successfully used in the UK. Other countries who recognise the WA & SA systems could certainly make use of a model like this.

6.1.1 Overall ethos of the model

Each of the respondents remarked that the model appears to tackle the main points addressed in the exploratory work and felt that it was, on the whole, a workable and well-considered model. It was appreciated that the major strength of the way that BSEs are educated and trained in the UK is through learning acquired by trainees in the workplace taking place alongside BEng and MEng educational programmes of a highly vocational and practical nature, and it is clear that this proposed model recognises and attempts to build upon this strength. The respondents all remarked that the proposed model could potentially fit alongside the newly developed degree apprenticeship (DA) structures, and as such it would be likely to be cautiously welcomed by the industry. This subject is examined further in Section 6.1.3.

All respondents considered that the model appears to be concise and well ordered, and shows very clear routes for progression. That the model includes defined routes to IEng and CEng and recognises the pathways of MEng and MSc progression (which are necessary because of the different academic offerings of those universities teaching BSE) with recognisable goals along the way was seen as very positive. One respondent, however, argued that greater differentiation between the IEng and CEng routes should perhaps be made possible. This would inevitably be very difficult to achieve with the BSE discipline because cohort sizes tend to be relatively small and such differentiation would be likely to lead to unsustainable student numbers.

All respondents remarked that the model represents a worthwhile attempt at allying professional competencies accumulated in work based learning with academic learning. The mapping of the WA and SA competencies and cross referencing these with the EC competencies for both the academic and work based learning parts of the model attracted several positive comments, and it was generally held that such a facility is likely to encourage students to focus on a career overseas.

6.1.2 Content of degree programme

The subject matter to be delivered within identified educational themes and the balance between these was generally well received by all of the interviewees.

Two of the respondents opined that they felt it was very important that traditional hand calculation methods and hand drawing of construction and BSE details be retained as fundamental skills, and would prefer to see these taught and practiced at the early stages of the course before students became reliant upon IT based methods. There is no real reason why this cannot be incorporated, and indeed, many BSE courses attempt to include such subject matter in the fundamental engineering skillset.

The respondents agreed that the breadth of curriculum as regards BSE specialist subjects seems sensible, though two respondents felt that there should perhaps be some scope for specialisation at levels 6 and 7 to delineate Electrical and Mechanical Services Engineering specialisms. It was, however, accepted that in university Engineering or Built Environment departments, BSE is usually one of the smaller courses, and thus the provision of optional study modules is often not feasible. If a course had a sufficiently large cohort there may be opportunity to include optional modules at levels 6 and 7 that allow for students to pursue specialisms. It was seen as important that the model should not seek to prescriptively define course content; rather it should define format, structure and suggest likely content.

6.1.3 Content of work based learning programme

It was generally believed that although work based learning does take place widely and some companies have developed excellent training courses, the lack of consistency across the industry can be an issue. It was generally accepted that the CIBSE's guidance on work based learning is very good as far as it goes, but is very general in nature. The notion of a thematic structure to work based learning, as advocated in this model was therefore seen as very positive.

There were concerns about where important subjects like engineering ethics sit within the three identified themes and about certain vocational skills that are vital to the BSE industry. There were several suggestions as to other themes that could be identified, monitored and assessed in the work based training programme, though there was some overlap between these suggestions and the themes already identified. The suggestions included:

- Using and promoting sustainable and low carbon technical solutions in BSE design work;
- BSE contracts management, including tendering and estimating;
- Health and safety: from the point of view of office and construction site environments, and for end users of BSE systems;
- The use of thermal modelling software in design work, and accurate interpretation of software models;
- Managing cost and finance on projects as part of project management roles;
- Personnel management, and managing sub-contractors.

In general, all respondents believed that, although the idea of imposing a structure, albeit a flexible one, on work based learning was sound, more research would be required to make this an entirely workable proposition. It was suggested that the BSE degree apprenticeships (DA) framework, which defines work based learning activities more closely, should be considered and the proposed model may be usefully aligned to this, notwithstanding certain difficulties, which are discussed below.

DAs have been very recently made available across a number of engineering, construction and built environment disciplines, though the framework for BSE has, at the time of writing, not yet been fully approved at governmental level. Although the DA frameworks follow a similar ethos of allying a work based training scheme with a degree qualification leading to demonstration of professional body requirements, none attempt to directly address the internationalist ideal which has been attempted here. DAs have the more modest aim of seeking to provide UK employers with systems and tools to develop engineers whilst mitigating the substantial costs of training and education. They are self-evidently not intended to address the wider global issue of the necessity of skilled labour being able to cross international borders to enhance sustainable development in an increasingly international economy.

In addition, DAs are only concerned with taking trainees up to IEng qualification, while the model is designed to allow progression to CEng qualification. All the respondents remarked that although this is something of a mismatch and the stated aims of DAs are rather less ambitious than those of the new model, this is not something that should deter further research and developmental work.

6.1.4 Applicability of the model

The respondents all considered that having a suitable structure to work based learning could be very useful for companies developing graduate training schemes, but warned against being too prescriptive (notwithstanding the consensus that the proposed structure needs further consideration). All welcomed the opportunity to match competencies gained in the workplace with UK-SPEC competencies and felt that relating competencies to the WA and SA would be a useful exercise. All respondents agreed that providing trainees with the opportunity to consider the WA and SA graduate and professional competencies could potentially make trainees more amenable to overseas working practices and appreciating engineering ethics from different cultural standpoints. One respondent remarked that requiring trainees to address the WA and SA competencies may be a step too far since the competencies listed in the UK-SPEC are universally accepted and, in any case, its systems fit comfortably enough alongside WSDA systems and the competencies could be identified at some later date should engineers wish to move overseas. However, this respondent did concede that this view somewhat misses the point of the internationalist approach championed in this research project, this being the wish to equip registrants with an internationalist skillset.

All participants tended to agree that consistency of educational approach could be better assured by having university courses available for part-time study from level 4 alongside full-time employment, and remarked that most university courses in BSE are only available part-time from levels 5 or 6. The interviewees agreed that a framework such as the one proposed in this model is certainly a good way of ensuring that coherent and well-structured degree level opportunities are made available to the many BSE trainees who currently must pursue HNC and HND college qualifications and then progress to university study at the higher levels.

In mitigation, it was not believed that this is inherently a bad system, and it was remarked that many college courses are excellent and teaching of engineering fundamentals can be very good, but it is generally perceived that transfer between different courses and different institutions can result in certain inconsistencies. There are many cases according to the academic respondents, where syllabi overlap, there can be repetition of teaching, and trainees are required to take unnecessarily long courses when universities' recognition of prior learning systems cause them (arguably) to be systematically placed at lower academic levels on university courses than they perhaps should.

The notion of a year abroad was generally welcomed and fits in with the ethos of many university courses, though the setting up and management of such a proposition would inevitably be fraught with administrative difficulties. Such an approach could, however, work for companies with overseas offices and make them attractive to potential employees. It was generally agreed that the overseas year of the programme could be in the second or third year of training where a suitable overseas university course was available. However, all participants believed that it is unlikely that such a course would be available and a more likely scenario would be that trainees could be posted overseas for a year after completion of their university studies to carry out work which leads towards demonstration of the professional competencies.

All respondents felt that the proposed model could work well in the UK, possibly under the guise of DAs, but doubted that the model could easily be exported. In some countries there is an innate appreciation of the value of work based learning, particularly in northern Europe, but in much of the world the academic output tends to be of primary interest and it is unlikely that a model such as this would be adopted. Should this model or something similar be adopted by the CIBSE and major international employers then this situation would undoubtedly be subject to change.

The consensus was that involvement of the CIBSE is key to such a model being generally accepted and ultimately successful. It was suggested that universities and major employers would need to manage the model in partnership and the overall framework would need to be accredited by the CIBSE.

All respondents felt that the lack of parity between Incorporated Engineers and Chartered Engineers cannot be properly addressed by this model, and the present situation where engineers often see IEng as a stepping stone to CEng is likely to be further reinforced. One respondent went so far as to say that for true demarcation of the Engineer and Technologist grades there should perhaps be a common first and second year of training, and then both the educational and work based training courses should completely diversify. It is difficult to see that this could be a workable proposition for university courses, as such courses tend to work with relatively small numbers of students, but in-company training schemes could certainly address this point. However, it was also observed that for true differentiation between IEng and CEng grades, the UK-SPEC's professional competencies would need to be substantially revised to reflect such a demarcation.

Chapter 7 – Conclusions

The title of this work suggests that the EC and the CIBSE have considerable influence on BSE education and training programmes, and the work has set out to examine whether this is generally advantageous or whether it mitigates against international mobility of UK trained BSEs. The work finds that in the UK and abroad, EC and CIBSE systems and procedures are largely seen as beneficial and fit for purpose by both the BSE industry and engineering community at large. The EC emerges as something of a world leader in facilitating international mutual recognition of engineers due to its highly developed systems for identifying and assessing individual professional competencies as well as defining overall the competence of professional engineers, its ability to adapt to fit other international systems, and its willingness to constantly review and adjust its own position and procedures in a changing world. In the BSE field, notwithstanding the influence of other major international institutions such as ASHRAE, the CIBSE remains well respected and influential.

From the perspective of UK educated and EC registered BSEs, the competencies that they must demonstrate for EC registration provide an impressive competitive edge in the international job market. As has been already argued, engineers from many other countries do not enjoy such an advantage since many national registration and licencing systems often take account of educational qualifications only. The proposed education and training model seeks therefore to build upon this strength, and could potentially serve to reinforce this advantage further for UK BSEs by introducing the international aspects outlined in Section 5.1.

The WA and SA are without doubt the main influences at present as the world strives towards international reciprocal recognition of engineering qualifications, and mutual recognition of engineer registration and licencing procedures across all disciplines, notwithstanding the myriad other systems seen throughout the developed and developing worlds. There are of course a great many discrepancies and inconsistencies seen throughout the world, though there is constant work underway to attempt to address this and there appears to be a genuine appreciation worldwide that the ideal of sustainable development can be very usefully advanced by international agreements and the mobility of skilled professionals across borders.

It is useful in this concluding chapter to revisit the specific research objectives set in the introduction and assess how these have been addressed in the work. This process of critical review enables the main headline conclusions and opportunities for further research to emerge.

7.1. UK focus

Initially the work focussed on an examination of the EC, the PEIs and CIBSE as a means of appreciating the way in which BSE study programmes are developed, how the EC influences the content and structure of these, and how effective BSE education and training are perceived to be. This work was carried out as a prelude to examining international recognition of qualifications and engineering competencies.

Objective 1 *– Examine the development of the EC and PEIs and critically review their influence on BSE academic programmes and qualifications.*

Objective 2 *– Investigate the introduction of the UK-SPEC and critically review the EC's approach for making judgements about the accreditation of academic programmes and registration of engineers.*

The recent history and development of the EC, the PEIs and specifically the CIBSE was catalogued in the initial literature review to set the scene for the research questions (see Sections 2.1, 2.2 and 2.3) and further critical examination was carried out in the exploratory semi-structured interviews to help develop further avenues of investigation. The quality of interrelationships between the PEIs and their levels of engagement with the EC emerged as a topic of investigation and was therefore further examined in the questionnaire survey. It was found, as hypothesised, that the smaller PEIs certainly appear to be less engaged and thus exert a lesser amount of influence within the EC, though several qualitative comments included in the questionnaire responses indicate that the EC works hard to maintain an inclusive ethos and to dutifully represent the views of all institutions.

Since this work focusses on the BSE discipline, the relative influence of the CIBSE was of more direct relevance than the standing of other institutions, though it was important to establish an understanding of the nature of the EC when reviewing its influence on engineering courses and accreditation. One of the important findings from the questionnaire and from the semi-structured interviews was that the CIBSE enjoys particularly strong influence both inside and outside the EC and it is also well respected internationally (see Section 4.4.6).

In the development of academic programmes in engineering disciplines it was found, unsurprisingly, that the influence of the EC is considerable, chiefly because it oversees an unquestionably robust course accreditation system (notwithstanding the occasional criticisms of inconsistency between the approaches of some PEIs). When examined in the context of international mutual recognition of qualifications, it becomes evident that the EC's accreditation system is well respected and is even recognised in many quarters abroad as something of an exemplar of good practice. This is particularly pertinent given that part of the ECs international mission is to facilitate reciprocal arrangements with other countries and encourage transparency and mutual recognition of engineering qualifications across borders.

More significantly to this thesis is the EC's influence on BSE courses, which is of course effected via the CIBSE, the EC licenced body representing the BSE industry. The CIBSE is a medium sized PEI, both in terms of raw member count and numbers of EC registrant members, and is itself perceived to have very robust and reliable systems and procedures for both HE course accreditation and engineer registration. From both the literature and data collection it was inferred that the CIBSE appears fully committed to the EC's overall philosophical stance, and consequentially adopts practices and procedures that entirely fulfil EC requirements and policies, whilst simultaneously representing the BSE industry most effectively.

The events which led to the introduction of the UK-SPEC were described in the literature review and the development of the professional engineering competency (PEC) statements was also described (see Section 2.4), these being a set of standard statements describing the individual competencies required for engineers to be professionally registered in the UK. The PEC statements are used by the PEIs as a means to assess applicants for entry to the UK Register of Engineers, and the UK-SPEC is further used by HEIs as a base line for course development. It was suggested in the exploratory interviews that the PECs are perhaps too general in nature to be able to represent all engineering disciplines well, and this view was examined in the questionnaire survey. The relative contributions of the various PEIs to the publication of the UK-SPEC and the drafting of the PECs was also similarly investigated. As hypothesised, it was found that the larger PEIs had been the most involved in the UK-SPEC and PEC drafting process, and the smaller PEIs appeared to feel less ownership of the UK-SPEC publication and less confidence that the PECs are entirely applicable to every engineering discipline (see Section 4.4.2). None of the questionnaire or interview responses, however, led to any suggestion that the UK-SPEC and PECs are in any way not fit for purpose. Significantly, the CIBSE respondents, despite acknowledging that the CIBSE had not been one of the lead institutions during the drafting of the UK-SPEC and PECs, were for the most part confident that the PECs were a comfortable fit for the BSE industry and registration of BSEs (see Section 4.5.1).

Objective 3 *– Critically evaluate the membership details of the PEIs and critically review the EC registration grades and PEI member categories.*

As an additional point of interest about the structure of the EC, further investigative work was carried out into the nature of the PEIs and their relative sizes using literature, the exploratory semi-structured interviews, and the questionnaire (see Section 2.2). It was established that some of the PEIs are not exclusively engineering institutions and represent other professions as well as engineers, and in some cases (for example the Institute of Physics) their primary business may actually be representing other professions and engineer representation is perhaps something of a side-line. When the number of EC registrant members is considered in relation to PEIs' total membership numbers, markedly different membership profiles are seen, and this correlates broadly with the levels of engagement between the PEIs and the EC. In general, leaving aside the largest four institutions (the IMechE, ICE, IET and BCS) whose membership numbers dwarf most of the others, those PEIs with a higher percentage of EC registrant members tend to be more engaged with EC affairs than those with a lower percentage of engineer members (see Section 4.4.2). This was perhaps to be expected, but again, testing this correlation using the questionnaire was a significant stage in building a picture of the EC.

Of more direct relevance to the question of BSE education and training was the investigation into the types of engineer registration and PEI membership. The three main grades of EC registration (EngTech, IEng and CEng) were critically examined using available literature (see Section 2.4) and in the exploratory and in-depth semi-structured interviews (see Section 4.5). It emerges that the CEng grade is the most sought after and is generally considered to be a "higher", and hence more worthy, grade of registration than IEng. IEng registration is seen often as a milestone towards CEng registration and the divide delineating the two classes is blurred. The official view of the EC is that both registration grades are equally valued by (and important to) industry, though as reported, there are six times as many CEng registrants as IEng registrants, and the common perceptions concerning the relative value of these categories and the hierarchical nature of the engineering professions remains an issue. It was also found that there are a disappointingly low number of EngTech registrants despite recent efforts in the UK to encourage potential registrants to come forward, though since this research project is concerned with degree level education and engineer registrations, this question was not considered further.

Objective 4 *– Examine how BSE study programmes are developed and the process of professional accreditation in the UK.*

Objective 5 *– Examine the educational and professional requirements for engineers to be registered to practise in the UK and overseas;*

Although the UK-SPEC is the standard publication for describing engineering competencies, the latest version of AHEP (AHEP 3 being the most recent) is used by HEIs to develop engineering academic programmes suitable for professional accreditation. An investigation was carried out into the nature of competence as a prelude to a critical examination of the way that BSE courses are developed in the UK to address the competencies specified in the UK-SPEC and AHEP 3 (see Section 2.6). It was found that there is a considerable amount in common between the various BSE courses since all courses must aspire towards CIBSE accreditation, and something of a generic blueprint emerges. In the field of BSE, the CIBSE publishes an interpretation of the UK-SPEC and AHEP requirements which course designers appear to find particularly useful.

The systems and procedures for course accreditation under the auspices of the EC were examined and catalogued and some comparisons were made with accreditation systems found overseas, and systems for international mutual recognition of accreditation systems. As described in Chapter 2, the PEIs operate under licence from the EC to accredit HE courses in their corresponding disciplines, and the CIBSE performs this function for the BSE discipline. The questionnaire and semi-structured interviews indicate that the CIBSE is perceived to have very robust and reliable accreditation systems and procedures.

The requirements for engineers in the two main categories (CEng and IEng) to be registered with the EC and to hold professional memberships in the UK, thus granting them authority to practice at engineer level, have been described and catalogued quite exhaustively in Section 2.4 of this work. The EngTech grade is also discussed for the sake of completeness, but a detailed examination of Technicians falls outside the scope of this work. It is found that due to the EC's considerable overseas reach that the UK registration titles are recognised and respected throughout much of the world. There are also international agreements, of which the EC is signatory, guaranteeing international recognition of UK qualified and registered engineers. As discussed and noted several times through the thesis, the most far-reaching set of international arrangements for reciprocal recognition of engineering qualifications and professional competencies are the WSDA agreements, to which the EC is a lead signatory.

7.2 International focus

Objective 6 *– Investigate and critically analyse international systems which are attempting to facilitate international transparency of engineering qualifications.*

Objective 7 *– Compare and contrast the main systems and procedures overseas for accrediting engineering academic programmes, recognising engineering competencies and registering/licencing engineers.*

As previously stated, the WSDA agreements are the main drivers towards international reciprocal recognition of engineering qualifications, engineer registration and licencing. There are of course discrepancies and inconsistencies seen throughout the world – too many to accurately catalogue – though there is constant work underway to attempt to address this. The drivers for such work include not just the strengthening of overseas trade links for developed economies like the USA, UK and EU nations (though undoubtedly these are important factors), there appears to be a genuine consensus worldwide that the ideal of sustainable development can be very usefully advanced by international agreements and the mobility of skilled professionals across borders.

The EUR-ACE accreditation system is undoubtedly a major positive influence in the international alignment of engineering courses, and its work does not in any way compromise the WSDA agreements, nor does it cut across the EC's systems. However, it seeks at present only to harmonise engineering education and national accreditation systems in member countries, and does not currently attempt to consider professional competencies in the way that the WSDA agreements do. Other mutual recognition systems seen through the world operate under the auspices of the IEA, and as mentioned previously these include the APECEA, the IPEA and the IETA, which deal with professional competencies rather than educational qualifications, and thus they do not have the wider remit of the WSDA agreements.

The USA's approach to mutual recognition of engineering qualifications is different to the EC's in that it advises, through the ABET, about the content and accreditation of university courses across the world, thus indirectly widening the influence of the WSDA. The EC's approach is, as previously noted, to define professional competencies and the requirements of academic qualifications from a national perspective, and from this position to work towards international mutual recognition of engineers through the WSDAs and other international agreements.

The future is therefore likely to see a widening of the WSDA agreements as they seek to further the ideal of mutual recognition of educational qualifications and professional competencies between the various international agreements in evidence across the world.

Objective 8 *– Elicit views as to the perceived value of a UK engineering education when practising abroad.*

This objective was explored chiefly in the semi-structured interviews (described in Sections 3.2.5 and 4.5.6), with respondents representing industry and PEIs at home and abroad, and academics with experience in the UK and overseas. As discussed, UK BSEs tend to be highly regarded and sought after in many countries with both developed and developing economies, and there is a common perception in several overseas destinations that UK trained BSEs exhibit high levels of self-confidence and occupational competence at comparatively young ages. UK BSEs are often regarded as safe to entrust with high degrees of responsibility.

The perception is that this is likely due in large part to the incidental (though often unstructured) work-based learning that takes place alongside part-time college and university attendance in the UK. It was also noted that in the UK there is a constant shortage of qualified BSEs, so young engineers must often accept high levels of responsibility whether they are ready for this or not. These arguments seem logical, but BSE education and training in many other countries appears to be carried out using similar mechanisms of part-time college/university attendance, so it is not immediately apparent why UK BSEs should be perceived to have the edge over locally trained professionals. This may perhaps be explained by another important point emerging from the semi-structured interviews: the EC's system of engineer registration is undoubtedly more established and dependable than comparable systems found in many parts of the world, and it therefore better facilitates the assimilation of professional competencies in the workplace. The CIBSE's system of supporting employers with structured workplace post-graduate training schemes was also viewed very positively in this light. It certainly appears that UK BSEs, are highly desirable across much of the world.

The main weakness identified in UK engineering education was that the EC and WSDA competencies are all drafted from the cultural perspective of Western industrialised nations and may not be able to address local political imperatives. There is certainly a (historical) perception that the WSDA agreements were originally implemented by an English speaking self-appointed elite, and thus the identified competencies and references to engineering ethics are not a comfortable fit in all parts of the world. There was a distinct view that UK BSEs tend to see complex cultural, political and socio-economic issues from a European standpoint and this can lead to some cultural discomfiture and professional misunderstandings.

7.3 Synthesis and testing of an education and training model

Objective 9 *– Elicit views about what an education and training model should encompass to facilitate internationalism in BSE education;*

Objective 10 *– Synthesise and critically evaluate an education and training model to promote internationalism in BSE.*

The model was developed and synthesised as discussed in Chapter 5 and some views as to its suitability and applicability were gathered as described in Chapter 6.

As a general principle the new education and training model was designed to build upon the previously identified strengths, whilst addressing the weaknesses of the UK's approach to education and training. The model therefore consists of degree courses meeting AHEP 3 standards running alongside workplace training schemes designed to allow trainees to assimilate the UK-SPEC competencies. The model was further designed to incorporate a coherent, though flexible time frame such that BSEs may qualify within a known timescale.

In order to make the model internationally applicable (as is the stated aim of this project), the degree course was designed to also meet WA and SA graduate standards, while the workplace training scheme was intended to meet WA and SA professional standards. An additional module was incorporated into the degree programme to impart a greater understanding of engineering ethics in relation to different world cultures, in an attempt to widen the education of engineers beyond the Western industrialised cultural mind-set. It was also suggested that engineering ethics and alternative cultural views be addressed during the work-based training scheme. The facility for a year to be spent abroad is also integral to the model, though this would need to be facilitated by the employer in collaboration with the HEI, so this is likely to prove problematic, though certainly not impossible, to realise.

Whilst not absolutely defining what should be taught and how it should be taught, the model is intended to be an exemplar academic programme, allied with a structured work based training programme, such that it may also be adapted to fulfil the requirements of other allied professions.

Comment and opinion about the model was sought in a final small set of semi-structured interviews from experts as described in Chapter 6. The respondents indicated generally that the model was a workable and well-considered proposition, the major strength being the allying of an appropriately structured workplace training course alongside a highly vocational BEng or MEng educational programme. The respondents all remarked that the proposed model could realistically, with some refinement, be adopted by the industry, particularly as it could potentially fit well alongside the newly developed structures for degree apprenticeships, though these do not attempt to address the internationalist ideal and do not facilitate the development of engineers beyond IEng registration. The notion of a year abroad was not discounted entirely, but all respondents pointed out the obvious problems with organising such a facility.

There were various suggestions as to how the educational content of the degree programmes might be refined, and many more suggestions as to possible improvements to the work-based learning part of the programme. All respondents remarked on the inclusion of a greater focus than at present on engineering ethics and cultural studies could make a real difference to young engineers thinking of working overseas, and greater internationalisation of the BSE industry could have a real impact on the global drive towards sustainable development in construction.

7.4 Further research

Following analysis and expert comments from the interview respondents, the new model would undoubtedly benefit from further development and refinement, particularly the work-based learning element. It would indeed be a useful exercise to explore how the model could fit alongside the framework for BSE degree apprenticeships, this being due for imminent government approval and implementation in the UK. Further developments relating to the model could be practically tested by further semi-structured interviews and focus groups involving other stakeholders, such as employers, training manager and mentors, BSEs in practice at home and abroad, and indeed trainees themselves.

In addition it would be a profitable line of research to explore the feasibility of using the newly developed education and training model in associated disciplines such as Civil Engineering, Mechanical Engineering and Electrical & Electronic Engineering. All these disciplines are considerably larger in terms of engineer numbers than BSE and the disciplines have considerable overlap, so such an examination could constitute a very viable and worthwhile course of further research and make adoption of the model much more likely.

Much of this work has been necessarily quite general in its treatment of overseas educational systems and practices for the registration and licencing of engineers, though the main systems in evidence have been highlighted, described and critically analysed. The task of conducting worldwide research is of course too extensive for a lone researcher and there is much more that could have been achieved had this project been carried out by a well-directed research team. Detailed comparisons between national and international course accreditation systems, and between engineer licencing and registration systems throughout the world would indeed be a useful future exercise if the model is to be further developed and ultimately made available for export.

On a related theme, since the model has been designed largely with the UK education and training system in mind, it would be extremely useful to examine how the model might be adapted to fit within dissimilar education and training systems in other countries. Such research could well provide additional developmental information to supplement the internationalist ethos and credentials of the model and further the likelihood of adoption. In addition, further detailed investigation of how the model could potentially fit within the EUR-ACE system would also be particularly useful given the afore-mentioned uncertainty of the UK's future relationship with Europe.

This work has not sought to include the various debates surrounding those who carry out much BSE work with lower levels of responsibility, such as Engineering Technicians (who may or may not be EngTech registrants) and their international equivalents. Such personnel, who are often not registered with (or licenced by) any regulatory bodies carry out significant quantities of detailed BSE work under the direction of Engineers and Technologists, who assume the professional responsibilities. It must be recognised that such job roles see far more variation in the interpretation of standards across the world and it is likely to be a far more difficult task to make international comparisons and formulate an internationalist approach, though it would undoubtedly be worthwhile to do so.

The lack of parity between Engineers (CEng registrants and their equivalents) and Technologists (IEng registrants and their equivalents) also requires further research work and comparison on a national and international basis. Ultimately, the defined job roles and responsibilities associated with the two types of professional, along with the competencies specified not just in the UK-SPEC, but in the WA and SA agreements need considerable thought and refinement if this issue is to ever be resolved.

7.5 Research contributions and summary

The practical part of this work was to synthesise an internationalist education and training model for the BSE discipline and carry out analysis as to the utility and value of this. The main research contribution is that such a model has been found not only to be feasible, but highly desirable, for several reasons, many of which have been mentioned in the previous commentary. In addition, other points have arisen which may likewise be viewed as research contributions.

Of particular regard is the less certain future of the UK's relationship with its European neighbours, and indeed with the rest of the world. The issue of the UK's changing international relationships was not prevalent at the time that the project was started and could not have been foreseen, but this became more significant as the work continued and certainly during the latter stages of the project. Notwithstanding the very special positions of the EC and the CIBSE on the world stage in the Engineering community, this high standing may not necessarily be assured in the longer term. The considered introduction of such an education and training model, endorsed by the CIBSE and major international BSE employers could well serve to strengthen the UK's position not just in BSE but in other related disciplines.

It was also not foreseen at the start of this research project that degree apprenticeships would be developed under governmental direction during the course of the work, and these are now ready to be offered in several engineering and associated built environment disciplines and are likely to also become available shortly in BSE. It is significant in that there is governmental recognition of employers' needs to train and develop engineers at reasonable cost, given the high price of university fees. It is also significant that there is a recognition that young people can benefit from gaining their degree alongside work experience, and would subsequently graduate without the burden of a student debt. Such considerations resonate strongly with the ethos of this newly developed education and training model and (as previously described) degree apprenticeships could provide a way forward for the implementation of the model.

Given the difficulty of attracting young people in the UK to take up careers in engineering generally, and BSE in particular, leads to questions about whether universities continue to see BSE as a sustainable HE discipline. The use of a model such as that developed in this work whereby the professional body (CIBSE in this case) and major employers become major stakeholders in the education and training process, rather than recipients as they largely are at present, could have a real impact on encouraging young people into the industry. The opportunity for a young person to embark upon a career that provides the security of employment and a salary alongside the opportunities to participate in an HE experience and possibly a year of work or study abroad, could make BSE a much more visible as a career choice and therefore more viable in HEIs.

Notwithstanding the recommendations for further work and refinements, this thesis suggests that an internationalist model for UK BSE education and training is certainly possible and even desirable. From the point of view of UK trained and educated BSEs wishing to work overseas this could certainly be seen as worthwhile and profitable work.

There is, however, a broader view to take: it is advocated that an improvement to the international mobility prospects of BSEs and associated professionals could well work towards a better mutual understanding of the issues surrounding sustainable development in the built environment. Buildings must, after all, become more energy efficient and sustainable throughout the whole of the world and BSEs will be instrumental in this.

As such, the findings, developments and conclusions arising from this thesis represent original and novel additions to knowledge.

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Appendices

Appendix 1 – Professional engineering competence statements

The following italicised text is reproduced directly from the UK-SPEC (EC, 2010).

The Competence and Commitment Standard for Engineering Technicians

Engineering Technicians are concerned with applying proven techniques and procedures to the solution of practical engineering problems. They carry supervisory or technical responsibility, and are competent to exercise creative aptitudes and skills within defined fields of technology. Professional Engineering Technicians contribute to the design, development, manufacture, commissioning, decommissioning, operation or maintenance of products, equipment, processes or services. Professional Engineering Technicians are required to apply safe systems of working.

Competence statements

Engineering Technicians must be competent throughout their working life, by virtue of their education, training and experience, to:		
A. Use engineering knowledge and understanding to apply technical and practical skills. *This includes the ability to:*	*A1*	*review and select appropriate techniques, procedures and methods to undertake tasks.*
	A2	*use appropriate scientific, technical or engineering principles.*
B. Contribute to the design, development, manufacture, construction, commissioning, operation or maintenance of products, equipment, processes, systems or services. *In this context, this includes the ability to:*	*B1*	*identify problems and apply diagnostic methods to identify causes and achieve satisfactory solutions*
	B2	*identify, organise and use resources effectively to complete tasks, with consideration for cost, quality, safety and environmental impact.*
C. Accept and exercise personal responsibility. *This may include the ability to:*	*C1*	*work reliably and effectively without close supervision, to the appropriate codes of practice*
	C2	*accept responsibility for work of self and others*
	C3	*accept, allocate and supervise technical and other tasks.*
D. Use effective communication and interpersonal skills. *This includes the ability to:*	*D1*	*use oral, written and electronic methods for the communication in English of technical and other information*
	D2	*work effectively with colleagues, clients, suppliers and the public.*
E. Make a personal commitment to an appropriate code of professional conduct, recognising obligations to society, the profession and the environment. *In order to satisfy this commitment, they must:*	*E1*	*comply with the Code of Conduct of their Licensed Institution or Professional Affiliate*
	E2	*manage and apply safe systems of work*
	E3	*undertake engineering work in a way that contributes to sustainable development*
	E4	*carry out continuing professional development, including opportunities for this offered by their Institution, to ensure competence in areas and at the level of future intended practice.*

The Competence and Commitment Standard for Incorporated Engineers

Incorporated Engineers maintain and manage applications of current and developing technology, and may undertake engineering design, development, manufacture, construction and operation. Incorporated Engineers are variously engaged in technical and commercial management and possess effective interpersonal skills.

Competence statements

Incorporated Engineers must be competent throughout their working life, by virtue of their education, training and experience, to:		
A. Use a combination of general and specialist engineering knowledge and understanding to apply existing and emerging technology.	*A1*	*Maintain and extend a sound theoretical approach to the application of technology in engineering practice.* *This could include an ability to:* • *Identify the limits of own personal knowledge and skills* • *Strive to extend own technological capability* • *Broaden and deepen own knowledge base through new applications and techniques.*
	A2	*Use a sound evidence-based approach to problem-solving and contribute to continuous improvement.* *This could include an ability to:* • *Establish users' requirements for improvement* • *Use market intelligence and knowledge of technological developments to promote and improve the effectiveness of engineering products, systems and services* • *Contribute to the evaluation and development of continuous improvement systems* • *Apply knowledge and experience to investigate and solve problems arising during engineering tasks and implement corrective action.*
B. Apply appropriate theoretical and practical methods to design, develop, manufacture, construct, commission, operate, maintain, decommission and re-cycle engineering processes, systems, services and products.	*B1*	*Identify, review and select techniques, procedures and methods to undertake engineering tasks.* *This could include an ability to:* • *Select a review methodology* • *Review the potential for enhancing engineering products, processes, systems and services, using evidence from best practice* • *Establish an action plan to implement the results of the review.*
	B2	*Contribute to the design and development of engineering solutions.* *This could include an ability to:* • *Contribute to the identification and specification of design and development requirements for engineering products, processes, systems and services* • *Identify potential operational problems and evaluate possible engineering solutions, taking account of cost, quality, safety, reliability, appearance, fitness for purpose and environmental impact* • *Contribute to the design of engineering solutions.*

	B3	*Implement design solutions and contribute to their evaluation.* *This could include an ability to:* • *Secure the resources required for implementation* • *Implement design solutions, taking account of critical constraints* • *Identify problems during implementation and take corrective action* • *Contribute to the evaluation of design solutions* • *Contribute to recommendations for improvement and actively learn from feedback on results.*
	C1	*Plan for effective project implementation.* *This could include an ability to:* • *Identify the factors affecting the project implementation* • *Prepare and agree implementation plans and method statements* • *Secure the necessary resources and confirm roles in project team* • *Apply the necessary contractual arrangements with other stakeholders (client, subcontractors, suppliers, etc.).*
C. Provide technical and commercial management.	*C2*	*Manage the planning, budgeting and organisation of tasks, people and resources.* *This could include an ability to:* • *Operate appropriate management systems* • *Work to the agreed quality standards, programme and budget, within legal and statutory requirements* • *Manage work teams, coordinating project activities* • *Identify variations from quality standards, programme and budgets, and take corrective action* • *Evaluate performance and recommend improvements.*
	C3	*Manage teams and develop staff to meet changing technical and managerial needs.* *This could include an ability to:* • *Agree objectives and work plans with teams and individuals* • *Identify team and individual needs, and plan for their development* • *Manage and support team and individual development* • *Assess team and individual performance, and provide feedback.*
	C4	*Manage continuous quality improvement.* *This could include an ability to:* • *Ensure the application of quality management principles by team members and colleagues* • *Manage operations to maintain quality standards* • *Evaluate projects and make recommendations for improvement.*

D. Demonstrate effective interpersonal skills.	*D1*	*Communicate in English with others at all levels.* *This could include an ability to:* • *Contribute to, chair and record meetings and discussions* • *Prepare letters, documents and reports on technical matters* • *Exchange information and provide advice to technical and non-technical colleagues.*
	D2	*Present and discuss proposals.* *This could include an ability to:* • *Prepare and deliver appropriate presentations* • *Manage debates with audiences* • *Feed the results back to improve the proposals.*
	D3	*Demonstrate personal and social skills.* *This could include an ability to:* • *Know and manage own emotions, strengths and weaknesses* • *Be aware of the needs and concerns of others* • *Be confident and flexible in dealing with new and changing interpersonal situations* • *Identify, agree and work towards collective goals* • *Create, maintain and enhance productive working relationships, and resolve conflicts.*
E. Demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment.	*E1*	*Comply with relevant codes of conduct.* *This could include an ability to:* • *Comply with the rules of professional conduct of own professional body* • *Manage work within all relevant legislation and regulatory frameworks, including social and employment legislation.*
	E2	*Manage and apply safe systems of work.* *This could include an ability to:* • *Identify and take responsibility for own obligations for health, safety and welfare issues* • *Manage systems that satisfy health, safety and welfare requirements* • *Develop and implement appropriate hazard identification and risk management systems* • *Manage, evaluate and improve these systems.*
	E3	*Undertake engineering activities in a way that contributes to sustainable development.* *This could include an ability to:* • *Operate and act responsibly, taking account of the need to progress environmental, social and economic outcomes simultaneously* • *Provide products and services which maintain and enhance the quality of the environment and community, and meet financial objectives* • *Understand and encourage stakeholder involvement in sustainable development.*

	E4	*Carry out continuing professional development necessary to maintain and enhance competence in own area of practice.* *This could include an ability to:* • *Undertake reviews of own development needs* • *Prepare action plans to meet personal and organisational objectives* • *Carry out planned (and unplanned) CPD activities* • *Maintain evidence of competence development* • *Evaluate CPD outcomes against the action plans* • *Assist others with their own CPD.*

The Competence and Commitment Standard for Chartered Engineers

Chartered Engineers are characterised by their ability to develop appropriate solutions to engineering problems, using new or existing technologies, through innovation, creativity and change. They might develop and apply new technologies, promote advanced designs and design methods, introduce new and more efficient production techniques, marketing and construction concepts, or pioneer new engineering services and management methods. Chartered Engineers are variously engaged in technical and commercial leadership and possess effective interpersonal skills.

Competence statements

Chartered Engineers must be competent throughout their working life, by virtue of their education, training and experience, to:		
Use a combination of general and specialist engineering knowledge and understanding to apply existing and emerging technology.	*A1*	*Maintain and extend a sound theoretical approach to the application of technology in engineering practice.* *This could include an ability to:* *Identify the limits of own personal knowledge and skills* *Strive to extend own technological capability* *Broaden and deepen own knowledge base through new applications and techniques.*
	A2	*Engage in the creative and innovative development of engineering technology and continuous improvement systems.* *This could include an ability to:* *Establish users' needs* *Assess marketing needs and contribute to marketing strategies* *Identify constraints and exploit opportunities for the development and transfer of technology within own chosen field* *Promote new applications when appropriate* *Secure the necessary intellectual property rights* *Develop and evaluate continuous improvement systems.*
Apply appropriate theoretical and practical methods to the analysis and solution of engineering problems.	*B1*	*Identify potential projects and opportunities.* *This could include an ability to:* *Explore the territory within own responsibility for new opportunities* *Review the potential for enhancing engineering products, processes, systems and services* *Use own knowledge of the employer's position to assess the viability of opportunities.*

	B2	*Conduct appropriate research, and undertake design and development of engineering solutions.* *This could include an ability to:* *Identify and agree appropriate research methodologies* *Assemble the necessary resources* *Carry out the necessary tests* *Collect, analyse and evaluate the relevant data* *Draft, present and agree design recommendations, taking account of cost, quality, safety, reliability, appearance, fitness for purpose and environmental impact* *Undertake engineering design.*
	B3	*Implement design solutions, and evaluate their effectiveness.* *This could include an ability to:* *Ensure that the application of the design results in the appropriate practical outcome* *Implement design solutions, taking account of critical constraints* *Determine the criteria for evaluating the design solutions* *Evaluate the outcome against the original specification* *Actively learn from feedback on results to improve future design solutions and build best practice.*
Provide technical and commercial leadership.	*C1*	*Plan for effective project implementation.* *This could include an ability to:* *Identify the factors affecting the project implementation* *Lead on preparing and agreeing implementation plans and method statements* *Ensure that the necessary resources are secured and brief the project team* *Negotiate the necessary contractual arrangements with other stakeholders (client, subcontractors, suppliers, etc.).*
	C2	*Plan, budget, organise, direct and control tasks, people and resources.* *This could include an ability to:* *Set up appropriate management systems* *Agree quality standards, programme and budget within legal and statutory requirements* *Organise and lead work teams, coordinating project activities* *Ensure that variations from quality standards, programme and budgets are identified, and that corrective action is taken* *Gather and evaluate feedback, and recommend improvements.*
	C3	*Lead teams and develop staff to meet changing technical and managerial needs.* *This could include an ability to:* *Agree objectives and work plans with teams and individuals* *Identify team and individual needs, and plan for their development* *Lead and support team and individual development* *Assess team and individual performance, and provide feedback.*
	C4	*Bring about continuous improvement through quality management.* *This could include an ability to:* *Promote quality throughout the organisation and its customer and supplier networks* *Develop and maintain operations to meet quality standards* *Direct project evaluation and propose recommendations for improvement.*

Demonstrate effective interpersonal skills.	*D1*	*Communicate in English with others at all levels.* *This could include an ability to:* *Contribute to, chair and record meetings and discussions* *Prepare letters, documents and reports on technical matters* *Exchange information and provide advice to technical and non-technical colleagues.*
	D2	*Present and discuss proposals.* *This could include an ability to:* *Prepare and deliver appropriate presentations* *Manage debates with audiences* *Feed the results back to improve the proposals.*
	D3	*Demonstrate personal and social skills.* *This could include an ability to:* *Know and manage own emotions, strengths and weaknesses* *Be aware of the needs and concerns of others* *Be confident and flexible in dealing with new and changing interpersonal situations* *Identify, agree and work towards collective goals* *Create, maintain and enhance productive working relationships, and resolve conflicts.*
Demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment.	*E1*	*Comply with relevant codes of conduct.* *This could include an ability to:* *Comply with the rules of professional conduct of own professional body* *Manage work within all relevant legislation and regulatory frameworks, including social and employment legislation.*
	E2	*Manage and apply safe systems of work.* *This could include an ability to:* *Identify and take responsibility for own obligations for health, safety and welfare issues* *Manage systems that satisfy health, safety and welfare requirements* *Develop and implement appropriate hazard identification and risk management systems* *Manage, evaluate and improve these systems.*
	E3	*Undertake engineering activities in a way that contributes to sustainable development.* *This could include an ability to:* *Operate and act responsibly, taking account of the need to progress environmental, social and economic outcomes simultaneously* *Provide products and services which maintain and enhance the quality of the environment and community, and meet financial objectives* *Understand and encourage stakeholder involvement in sustainable development.*

	E4	*Carry out continuing professional development necessary to maintain and enhance competence in own area of practice.* *This could include an ability to:* *Undertake reviews of own development needs* *Prepare action plans to meet personal and organisational objectives* *Carry out planned (and unplanned) CPD activities* *Maintain evidence of competence development* *Evaluate CPD outcomes against the action plans* *Assist others with their own CPD.*

Appendix 2 – Learning outcomes for EC accredited courses

The following is reproduced from the EC publication *Accreditation of Higher Education Programmes: UK Standard for Professional Engineering Competence* (AHEP 3) (EC, 2014). The shorthand designations relating to each learning outcome are taken from CIBSE guidance notes issued to accredited course providers.

Bachelors Degrees and Bachelors (Honours) Degrees accredited for IEng registration

Subject area	***Designation***	***Learning outcomes***
Science and mathematics (SM)	*SM1i*	*Knowledge and understanding of the scientific principles underpinning relevant current technologies, and their evolution*
	SM2i	*Knowledge and understanding of mathematics and an awareness of statistical methods necessary to support application of key engineering principles.*
Engineering analysis (EA)	*EA1i*	*Ability to monitor, interpret and apply the results of analysis and modelling in order to bring about continuous improvement*
	EA2i	*Ability to apply quantitative methods in order to understand the performance of systems and components*
	EA3i	*Ability to use the results of engineering analysis to solve engineering problems and to recommend appropriate action*
	EA4i	*Ability to apply an integrated or systems approach to engineering problems through know-how of the relevant technologies and their application.*
Design (D)	*D1i*	*Be aware of business, customer and user needs, including considerations such as the wider engineering context, public perception and aesthetics*
	D2i	*Define the problem, identifying any constraints including environmental and sustainability limitations; ethical, health, safety, security and risk issues; intellectual property; codes of practice and standards*
	D3	*Work with information that may be incomplete or uncertain and be aware that this may affect the design*
	D4i	*Apply problem-solving skills, technical knowledge and understanding to create or adapt design solutions that are fit for purpose including operation, maintenance, reliability etc*
	D5	*Manage the design process, including cost drivers, and evaluate outcomes*
	D6	*Communicate their work to technical and non-technical audiences.*
Economic, legal, social, ethical and environmental context (EL)	*EL1*	*Understanding of the need for a high level of professional and ethical conduct in engineering and a knowledge of professional codes of conduct*
	EL2	*Knowledge and understanding of the commercial, economic and social context of engineering processes*

Subject area	***Designation***	***Learning outcomes***
	EL3i	*Knowledge of management techniques that may be used to achieve engineering objectives*
	EL4	*Understanding of the requirement for engineering activities to promote sustainable development*
	EL5	*Awareness of relevant legal requirements governing engineering activities, including personnel, health & safety, contracts, intellectual property rights, product safety and liability issues*
	EL6i	*Awareness of risk issues, including health & safety, environmental and commercial risk.*
Engineering practice (P)	*P1i*	*Knowledge of contexts in which engineering knowledge can be applied (eg operations and management, application and development of technology, etc)*
	P2i	*Understanding of and ability to use relevant materials, equipment, tools, processes, or products*
	P3i	*Knowledge and understanding of workshop and laboratory practice*
	P4i	*Ability to use and apply information from technical literature*
	P6i	*Ability to use appropriate codes of practice and industry standards*
	P7	*Awareness of quality issues and their application to continuous improvement*
	P11i	*Awareness of team roles and the ability to work as a member of an engineering team.*
Additional general skills (G)	*G1*	*Apply their skills in problem solving, communication, information retrieval, working with others and the effective use of general IT facilities*
	G2	*Plan self-learning and improve performance, as the foundation for lifelong learning/CPD*
	G3	*Plan and carry out a personal programme of work*
	G4	*Exercise personal responsibility, which may be as a team member.*

Bachelors (Honours) Degrees accredited as partially meeting the educational requirement for CEng
(Further learning to Masters level will be required)

Subject area	***Designation***	***Learning outcomes***
Science and mathematics (SM)	*SM1b*	*Knowledge and understanding of scientific principles and methodology necessary to underpin their education in their engineering discipline, to enable appreciation of its scientific and engineering context, and to support their understanding of relevant historical, current and future developments and technologies*
	SM2b	*Knowledge and understanding of mathematical and statistical methods necessary to underpin their education in their engineering discipline and to enable them to apply mathematical and statistical methods, tools and notations proficiently in the analysis and solution of engineering problems*
	SM3m	*Ability to apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline.*
Engineering analysis (EA)	*EA1b*	*Understanding of engineering principles and the ability to apply them to analyse key engineering processes*
	EA2	*Ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques*
	EA3b	*Ability to apply quantitative and computational methods in order to solve engineering problems and to implement appropriate action*
	EA4b	*Understanding of, and the ability to apply, an integrated or systems approach to solving engineering problems.*
Design (D)	*D1*	*Understand and evaluate business, customer and user needs, including considerations such as the wider engineering context, public perception and aesthetics*
	D2	*Investigate and define the problem, identifying any constraints including environmental and sustainability limitations; ethical, health, safety, security and risk issues; intellectual property; codes of practice and standards*
	D3	*Work with information that may be incomplete or uncertain and quantify the effect of this on the design*
	D4	*Apply advanced problem-solving skills, technical knowledge and understanding, to establish rigorous and creative solutions that are fit for purpose for all aspects of the problem including production, operation, maintenance and disposal*
	D5	*Plan and manage the design process, including cost drivers, and evaluate outcomes*
	D6	*Communicate their work to technical and non-technical audiences.*
Economic, legal, social, ethical and environmental context (EL)	*EL1*	*Understanding of the need for a high level of professional and ethical conduct in engineering and a knowledge of professional codes of conduct*
	EL2	*Knowledge and understanding of the commercial, economic and social context of engineering processes*
	EL3	*Knowledge and understanding of management techniques, including project management, that may be used to achieve engineering objectives*

Subject area	**Designation**	**Learning outcomes**
	EL4	*Understanding of the requirement for engineering activities to promote sustainable development and ability to apply quantitative techniques where appropriate*
	EL5	*Awareness of relevant legal requirements governing engineering activities, including personnel, health & safety, contracts, intellectual property rights, product safety and liability issues*
	EL6	*Knowledge and understanding of risk issues, including health & safety, environmental and commercial risk, and of risk assessment and risk management techniques.*
Engineering practice (P)	*P1*	*Understanding of contexts in which engineering knowledge can be applied (eg operations and management, application and development of technology, etc)*
	P2	*Knowledge of characteristics of particular materials, equipment, processes, or products*
	P3	*Ability to apply relevant practical and laboratory skills*
	P4	*Understanding of the use of technical literature and other information sources*
	P5	*Knowledge of relevant legal and contractual issues*
	P6	*Understanding of appropriate codes of practice and industry standards*
	P7	*Awareness of quality issues and their application to continuous improvement*
	P8	*Ability to work with technical uncertainty*
	P11	*Understanding of, and the ability to work in, different roles within an engineering team.*
Additional general skills (G)	*G1*	*Apply their skills in problem solving, communication, working with others, information retrieval, and the effective use of general IT facilities*
	G2	*Plan self-learning and improve performance, as the foundation for lifelong learning/CPD*
	G3	*Plan and carry out a personal programme of work, adjusting where appropriate*
	G4	*Exercise initiative and personal responsibility, which may be as a team member or leader.*

Integrated Masters (MEng) Degrees

Subject area	***Designation***	***Learning outcomes***
Science and mathematics (SM)	*SM1m*	*A comprehensive knowledge and understanding of scientific principles and methodology necessary to underpin their education in their engineering discipline, and an understanding and know-how of the scientific principles of related disciplines, to enable appreciation of the scientific and engineering context, and to support their understanding of relevant historical, current and future developments and technologies*
	SM2m	*Knowledge and understanding of mathematical and statistical methods necessary to underpin their education in their engineering discipline and to enable them to apply a range of mathematical and statistical methods, tools and notations proficiently and critically in the analysis and solution of engineering problems*
	SM3m	*Ability to apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline and the ability to evaluate them critically and to apply them effectively*
	SM4m	*Awareness of developing technologies related to own specialisation*
	SM5m	*A comprehensive knowledge and understanding of mathematical and computational models relevant to the engineering discipline, and an appreciation of their limitations*
	SM6m	*Understanding of concepts from a range of areas, including some outside engineering, and the ability to evaluate them critically and to apply them effectively in engineering projects.*
Engineering analysis (EA)	*EA1m*	*Understanding of engineering principles and the ability to apply them to undertake critical analysis of key engineering processes*
	EA2	*Ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques*
	EA3m	*Ability to apply quantitative and computational methods, using alternative approaches and understanding their limitations, in order to solve engineering problems and to implement appropriate action*
	EA4m	*Understanding of, and the ability to apply, an integrated or systems approach to solving complex engineering problems*
	EA5m	*Ability to use fundamental knowledge to investigate new and emerging technologies*
	EA6m	*Ability to extract and evaluate pertinent data and to apply engineering analysis techniques in the solution of unfamiliar problems.*
Design (D)	*D1*	*Understand and evaluate business, customer and user needs, including considerations such as the wider engineering context, public perception and aesthetics*
	D2	*Investigate and define the problem, identifying any constraints including environmental and sustainability limitations; ethical, health, safety, security and risk issues; intellectual property; codes of practice and standards*
	D3m	*Work with information that may be incomplete or uncertain, quantify the effect of this on the design and, where appropriate, use theory or experimental research to mitigate deficiencies*

Subject area	***Designation***	***Learning outcomes***
	D4	*Apply advanced problem-solving skills, technical knowledge and understanding to establish rigorous and creative solutions that are fit for purpose for all aspects of the problem including production, operation, maintenance and disposal*
	D5	*Plan and manage the design process, including cost drivers, and evaluate outcomes*
	D6	*Communicate their work to technical and non-technical audiences*
	D7m	*Demonstrate wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations*
	D8m	*Demonstrate the ability to generate an innovative design for products, systems, components or processes to fulfil new needs.*
Economic, legal, social, ethical and environmental context (EL)	*EL1m*	*Understanding of the need for a high level of professional and ethical conduct in engineering, a knowledge of professional codes of conduct and how ethical dilemmas can arise*
	EL2	*Knowledge and understanding of the commercial, economic and social context of engineering processes*
	EL3m	*Knowledge and understanding of management techniques, including project and change management, that may be used to achieve engineering objectives, their limitations and how they may be applied appropriately*
	EL4	*Understanding of the requirement for engineering activities to promote sustainable development and ability to apply quantitative techniques where appropriate*
	EL5m	*Awareness of relevant legal requirements governing engineering activities, including personnel, health & safety, contracts, intellectual property rights, product safety and liability issues, and an awareness that these may differ internationally*
	EL6m	*Knowledge and understanding of risk issues, including health & safety, environmental and commercial risk, risk assessment and risk management techniques and an ability to evaluate commercial risk*
	EL7m	*Understanding of the key drivers for business success, including innovation, calculated commercial risks and customer satisfaction.*
Engineering practice (P)	*P1*	*Understanding of contexts in which engineering knowledge can be applied (eg operations and management, application and development of technology, etc)*
	P2m	*Knowledge of characteristics of particular equipment, processes, or products, with extensive knowledge and understanding of a wide range of engineering materials and components*
	P3	*Ability to apply relevant practical and laboratory skills*
	P4	*Understanding of the use of technical literature and other information sources*
	P5	*Knowledge of relevant legal and contractual issues*
	P6	*Understanding of appropriate codes of practice and industry standards*
	P7	*Awareness of quality issues and their application to continuous improvement*
	P8	*Ability to work with technical uncertainty*

Subject area	***Designation***	***Learning outcomes***
	P9m	*A thorough understanding of current practice and its limitations, and some appreciation of likely new developments*
	P10m	*Ability to apply engineering techniques taking account of a range of commercial and industrial constraints*
	P11m	*Understanding of different roles within an engineering team and the ability to exercise initiative and personal responsibility, which may be as a team member or leader.*
Additional general skills (G)	*G1*	*Apply their skills in problem solving, communication, working with others, information retrieval and the effective use of general IT facilities*
	G2	*Plan self-learning and improve performance, as the foundation for lifelong learning/CPD*
	G3m	*Monitor and adjust a personal programme of work on an on-going basis*
	G4	*Exercise initiative and personal responsibility, which may be as a team member or leader.*

Masters Degrees other than the Integrated Masters (MEng)

Subject area	***Designation***	***Learning outcomes***
Science and mathematics (SM)	*SM7M*	*A comprehensive understanding of the relevant scientific principles of the specialisation*
	SM8M	*A critical awareness of current problems and/or new insights most of which is at, or informed by, the forefront of the specialisation*
	SM9M	*Understanding of concepts relevant to the discipline, some from outside engineering, and the ability to evaluate them critically and to apply them effectively, including in engineering projects.*
Engineering analysis (EA)	*EA6M*	*Ability both to apply appropriate engineering analysis methods for solving complex problems in engineering and to assess their limitations*
	EA5m	*Ability to use fundamental knowledge to investigate new and emerging technologies*
	EA7M	*Ability to collect and analyse research data and to use appropriate engineering analysis tools in tackling unfamiliar problems, such as those with uncertain or incomplete data or specifications, by the appropriate innovation, use or adaptation of engineering analytical methods.*
Design	*D9M*	*Knowledge, understanding and skills to work with information that may be incomplete or uncertain, quantify the effect of this on the design and, where appropriate, use theory or experimental research to mitigate deficiencies*
	D10M	*Knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations*
	D11M	*Ability to generate an innovative design for products, systems, components or processes to fulfil new needs.*
Economic, legal, social, ethical and environmental context (EL)	*EL8M*	*Awareness of the need for a high level of professional and ethical conduct in engineering*
	EL9M	*Awareness that engineers need to take account of the commercial and social contexts in which they operate*
	EL10M	*Knowledge and understanding of management and business practices, their limitations, and how these may be applied in the context of the particular specialisation*
	EL11M	*Awareness that engineering activities should promote sustainable development and ability to apply quantitative techniques where appropriate*
	EL12M	*Awareness of relevant regulatory requirements governing engineering activities in the context of the particular specialisation*
	EL13M	*Awareness of and ability to make general evaluations of risk issues in the context of the particular specialisation, including health & safety, environmental and commercial risk.*
Engineering practice (P)	*P12M*	*Advanced level knowledge and understanding of a wide range of engineering materials and components*
	P9m	*A thorough understanding of current practice and its limitations, and some appreciation of likely new developments*
	P10m	*Ability to apply engineering techniques, taking account of a range of commercial and industrial constraints*
	P11m	*Understanding of different roles within an engineering team and the ability to exercise initiative and personal responsibility, which may be as a team member or leader.*
Additional general skills (G)	*G1*	*Apply their skills in problem solving, communication, information retrieval, working with others, and the effective use of general IT facilities*
	G2	*Plan self-learning and improve performance, as the foundation for lifelong learning/CPD*

Subject area	***Designation***	***Learning outcomes***
	G3m	*Monitor and adjust a personal programme of work on an on-going basis*
	G4	*Exercise initiative and personal responsibility, which may be as a team member or leader.*

Appendix 3 – Professional engineering competencies specified by the WSDAs

The italicised text and tables below are reproduced directly from the IEA publication *Graduate Attributes and Professional Competencies* (IEA, 2013b) and concern both graduate attribute profiles and professional competency profiles. The first two tables must be read in conjunction with the following three, which define context, range of engineering activities and knowledge expectations.

Graduate Attribute Profiles

References to the Knowledge Profile are shown thus: (WK1 to WK4)

Differentiating Characteristic	***… for Washington Accord Graduate***	***… for Sydney Accord Graduate***	***… for Dublin Accord Graduate***
Engineering Knowledge:	***WA1:*** *Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to the solution of complex engineering problems.*	***SA1:*** *Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in SK1 to SK4 respectively to defined and applied engineering procedures, processes, systems or methodologies.*	***DA1:*** *Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in DK1 to DK4 respectively to wide practical procedures and practices.*
Problem Analysis *Complexity of analysis*	***WA2:*** *Identify, formulate, research literature and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. (WK1 to WK4)*	***SA2:*** *Identify, formulate, research literature and analyse broadly-defined engineering problems reaching substantiated conclusions using analytical tools appropriate to the discipline or area of specialisation. (SK1 to SK4)*	***DA2:*** *Identify and analyse well-defined engineering problems reaching substantiated conclusions using codified methods of analysis specific to their field of activity. (DK1 to DK4)*
Design/ development of solutions: *Breadth and uniqueness of engineering problems i.e. the extent to which problems are original and to which solutions have previously been identified or codified*	***WA3:*** *Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. (WK5)*	***SA3:*** *Design solutions for broadly-defined engineering technology problems and contribute to the design of systems, components or processes to meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. (SK5)*	***DA3:*** *Design solutions for well-defined technical problems and assist with the design of systems, components or processes to meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. (DK5)*
Investigation: *Breadth and depth of investigation and experimentation*	***WA4:*** *Conduct investigations of complex problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.*	***SA4:*** *Conduct investigations of broadly-defined problems; locate, search and select relevant data from codes, data bases and literature (SK8), design and conduct experiments to provide valid conclusions.*	***DA4:*** *Conduct investigations of well-defined problems; locate and search relevant codes and catalogues, conduct standard tests and measurements.*
Modern Tool Usage: *Level of understanding of the appropriateness of the tool*	***WA5:*** *Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering problems, with an understanding of the limitations. (WK6)*	***SA5:*** *Select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to broadly-defined engineering problems, with an understanding of the limitations. (SK6)*	***DA5:*** *Apply appropriate techniques, resources, and modern engineering and IT tools to well-defined engineering problems, with an awareness of the limitations. (DK6)*

The Engineer and Society: *Level of knowledge and responsibility*	***WA6:*** *Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems. (WK7)*	***SA6:*** *Demonstrate understanding of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering technology practice and solutions to broadly defined engineering problems. (SK7)*	***DA6:*** *Demonstrate knowledge of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering technician practice and solutions to well defined engineering problems. (DK7)*
Environment and Sustainability: *Type of solutions.*	***WA7:*** *Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts. (WK7)*	***SA7:*** *Understand and evaluate the sustainability and impact of engineering technology work in the solution of broadly defined engineering problems in societal and environmental contexts. (SK7)*	***DA7:*** *Understand and evaluate the sustainability and impact of engineering technician work in the solution of well-defined engineering problems in societal and environmental contexts. (DK7)*
Ethics: *Understanding and level of practice*	***WA8:*** *Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice. (WK7)*	***SA8:*** *Understand and commit to professional ethics and responsibilities and norms of engineering technology practice. (SK7)*	***DA8:*** *Understand and commit to professional ethics and responsibilities and norms of technician practice. (DK7)*
Individual and Team work: *Role in and diversity of team*	***WA9:*** *Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.*	***SA9:*** *Function effectively as an individual, and as a member or leader in diverse teams.*	***DA9:*** *Function effectively as an individual, and as a member in diverse technical teams.*
Communication: *Level of communication according to type of activities performed*	***WA10:*** *Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.*	***SA10:*** *Communicate effectively on broadly- defined engineering activities with the engineering community and with society at large, by being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions*	***DA10:*** *Communicate effectively on well-defined engineering activities with the engineering community and with society at large, by being able to comprehend the work of others, document their own work, and give and receive clear instructions*
Project Management and Finance: *Level of management required for differing types of activity*	***WA11:*** *Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.*	***SA11:*** *Demonstrate knowledge and understanding of engineering management principles and apply these to one's own work, as a member or leader in a team and to manage projects in multidisciplinary environments.*	***DA11:*** *Demonstrate knowledge and understanding of engineering management principles and apply these to one's own work, as a member or leader in a technical team and to manage projects in multidisciplinary environments*
Lifelong learning: *Preparation for and depth of continuing learning.*	***WA12:*** *Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.*	***SA12:*** *Recognize the need for, and have the ability to engage in independent and life-long learning in specialist technologies.*	***DA12:*** *Recognize the need for, and have the ability to engage in independent updating in the context of specialized technical knowledge.*

Professional Competency Profiles

To meet the minimum standard of competence a person must demonstrate that he/she is able to practice competently in his/her practice area to the standard expected of a reasonable Professional Engineer/Engineering Technologist/Engineering Technician.

The extent to which the person is able to perform each of the following elements in his/her practice area must be taken into account in assessing whether or not he/she meets the overall standard.

Differentiating Characteristic	***Professional Engineer***	***Engineering Technologist***	***Engineering Technician***
Comprehend and apply universal knowledge: *Breadth and depth of education and type of knowledge*	***EC1:*** *Comprehend and apply advanced knowledge of the widely-applied principles underpinning good practice*	***TC1:*** *Comprehend and apply the knowledge embodied in widely accepted and applied procedures, processes, systems or methodologies*	***NC1:*** *Comprehend and apply knowledge embodied in standardised practices*
Comprehend and apply local knowledge: *Type of local knowledge*	***EC2:*** *Comprehend and apply advanced knowledge of the widely-applied principles underpinning good practice specific to the jurisdiction in which he/she practices.*	***TC2:*** *Comprehend and apply the knowledge embodied procedures, processes, systems or methodologies that is specific to the jurisdiction in which he/she practices.*	***NC2:*** *Comprehend and apply knowledge embodied in standardised practices specific to the jurisdiction in which he/she practices.*
Problem analysis: *Complexity of analysis*	***EC3:*** *Define, investigate and analyse complex problems*	***TC3:*** *Identify, clarify, and analyse broadly- defined problems*	***NC3:*** *Identify, state and analyse well-defined problems*
Design and development of solutions: *Nature of the problem and uniqueness of the solution*	***EC4:*** *Design or develop solutions to complex problems*	***TC4:*** *Design or develop solutions to broadly- defined problems*	***NC4:*** *Design or develop solutions to well-defined problems*
Evaluation: *Type of activity*	***EC5:*** *Evaluate the outcomes and impacts of complex activities*	***TC4:*** *Evaluate the outcomes and impacts of broadly defined activities*	***NC5:*** *Evaluate the outcomes and impacts of well-defined activities*
Protection of society: *Types of activity and responsibility to public*	***EC6:*** *Recognise the reasonably foreseeable social, cultural and environmental effects of complex activities generally, and have regard to the need for sustainability; recognise that the protection of society is the highest priority*	***TC6:*** *Recognise the reasonably foreseeable social, cultural and environmental effects of broadly-defined activities generally, and have regard to the need for sustainability; take responsibility in all these activities to avoid putting the public at risk.*	***NC6:*** *Recognise the reasonably foreseeable social, cultural and environmental effects of well-defined activities generally, and have regard to the need for sustainability; use engineering technical expertise to prevent dangers to the public.*
Legal and regulatory: *No differentiation in this characteristic*	***EC7:*** *Meet all legal and regulatory requirements and protect public health and safety in the course of his or her activities*	***TC7:*** *Meet all legal and regulatory requirements and protect public health and safety in the course of his or her activities*	***NC7:*** *Meet all legal and regulatory requirements and protect public health and safety in the course of his or her activities*
Ethics: *No differentiation in this characteristic*	***EC8:*** *Conduct his or her activities ethically*	***TC8:*** *Conduct his or her activities ethically*	***NC8:*** *Conduct his or her activities ethically*
Manage engineering activities: *Types of activity*	***EC9:*** *Manage part or all of one or more complex activities*	***TC9:*** *Manage part or all of one or more broadly-defined activities*	***NC9:*** *Manage part or all of one or more well- defined activities*
Communication: *No differentiation in this characteristic*	***EC10:*** *Communicate clearly with others in the course of his or her activities*	***TC10:*** *Communicate clearly with others in the course of his or her activities*	***NC10:*** *Communicate clearly with others in the course of his or her activities*
Lifelong learning: *Preparation for and depth of continuing learning.*	***EC11:*** *Undertake CPD activities sufficient to maintain and extend his or her competence*	***TC11:*** *Undertake CPD activities sufficient to maintain and extend his or her competence*	***NC11:*** *Undertake CPD activities sufficient to maintain and extend his or her competence*

Judgement: *Level of developed knowledge, and ability and judgement in relation to type of activity*	***EC11:*** *Recognize complexity and assess alternatives in light of competing requirements and incomplete knowledge. Exercise sound judgement in the course of his or her complex activities*	***TC12:*** *Choose appropriate technologies to deal with broadly defined problems. Exercise sound judgement in the course of his or her broadly-defined activities*	***NC12:*** *Choose and apply appropriate technical expertise. Exercise sound judgement in the course of his or her well-defined activities*
Responsibility for decisions: *Type of activity for which responsibility is taken*	***EC12:*** *Be responsible for making decisions on part or all of complex activities*	***TC13:*** *Be responsible for making decisions on part or all of one or more broadly defined Activities*	***NC13:*** *Be responsible for making decisions on part or all of all of one or more well-defined activities.*

Common Range and Contextual Definitions

References to the Knowledge Profile are shown thus: (WK3, WK4 …)

In the context of both Graduate Attributes and Professional Competencies:			
Attribute	***Complex Engineering Problems*** *have characteristic WP1 and some or all of WP2 to WP7:*	***Broadly-defined Engineering Problems*** *have characteristic SP1 and some or all of SP2 to SP7:*	***Well-defined Engineering Problems*** *have characteristic DP1 and some or all of DP2 to DP7:*
Depth of Knowledge Required	***WP1:*** *Cannot be resolved without in-depth engineering knowledge at the level of one or more of WK3, WK4, WK5, WK6 or WK8 which allows a fundamentals-based, first principles analytical approach*	***SP1:*** *Cannot be resolved without engineering knowledge at the level of one or more of SK4, SK5, and SK6 supported by SK3 with a strong emphasis on the application of developed technology*	***DP1:*** *Cannot be resolved without extensive practical knowledge as reflected in DK5 and DK6 supported by theoretical knowledge defined in DK3 and DK4*
Range of conflicting requirements	***WP2:*** *Involve wide-ranging or conflicting technical, engineering and other issues*	***SP2:*** *Involve a variety of factors which may impose conflicting constraints*	***DP2:*** *Involve several issues, but with few of these exerting conflicting constraints*
Depth of analysis required	***WP3:*** *Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models*	***SP3:*** *Can be solved by application of well-proven analysis techniques*	***DP3:*** *Can be solved in standardised ways*
Familiarity of issues	***WP4:*** *Involve infrequently encountered issues*	***SP4:*** *Belong to families of familiar problems which are solved in well-accepted ways*	***DP4:*** *Are frequently encountered and thus familiar to most practitioners in the practice area*
Extent of applicable codes	***WP5:*** *Are outside problems encompassed by standards and codes of practice for professional engineering*	***SP5:*** *May be partially outside those encompassed by standards or codes of practice*	***DP5:*** *Are encompassed by standards and/or documented codes of practice*
Extent of stakeholder involvement and conflicting requirements	***WP6:*** *Involve diverse groups of stakeholders with widely varying needs*	***SP6:*** *Involve several groups of stakeholders with differing and occasionally conflicting needs*	***DP6:*** *Involve a limited range of stakeholders with differing needs*
Interdependence	***WP 7:*** *Are high level problems including many component parts or sub-problems*	***SP7:*** *Are parts of, or systems within complex engineering problems*	***DP7:*** *Are discrete components of engineering systems*
In addition, in the context of the Professional Competencies			
Consequences	***EP1:*** *Have significant consequences in a range of contexts*	***TP1:*** *Have consequences which are important locally, but may extend more widely*	***NP1:*** *Have consequences which are locally important and not far-reaching*
Judgement	***EP2:*** *Require judgement in decision making*	***TP2:*** *Require judgement in decision making*	

Range of Engineering Activities

Attribute	***Complex Activities***	***Broadly-defined Activities***	***Well-defined Activities***
Preamble	***Complex activities** means (engineering) activities or projects that have some or all of the following characteristics:*	***Broadly defined activities** means (engineering) activities or projects that have some or all of the following characteristics:*	***Well-defined activities** means (engineering) activities or projects that have some or all of the following characteristics:*
Range of resources	***EA1:** Involve the use of diverse resources (and for this purpose resources includes people, money, equipment, materials, information and technologies)*	***TA1:** Involve a variety of resources (and for this purposes resources includes people, money, equipment, materials, information and technologies)*	***NA1:** Involve a limited range of resources (and for this purpose resources includes people, money, equipment, materials, information and technologies)*
Level of interactions	***EA2:** Require resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering or other issues,*	***TA2:** Require resolution of occasional interactions between technical, engineering and other issues, of which few are conflicting*	***NA2:** Require resolution of interactions between limited technical and engineering issues with little or no impact of wider issues*
Innovation	***EA3:** Involve creative use of engineering principles and research-based knowledge in novel ways.*	***TA3:** Involve the use of new materials, techniques or processes in non-standard ways*	***NA3:** Involve the use of existing materials techniques, or processes in modified or new ways*
Consequences to society and the environment	***EA4:** Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation*	***TA4:** Have reasonably predictable consequences that are most important locally, but may extend more widely*	***NA4:** Have consequences that are locally important and not far-reaching*
Familiarity	***EA5:** Can extend beyond previous experiences by applying principles-based approaches*	***TA5:** Require a knowledge of normal operating procedures and processes*	***NA5:** Require a knowledge of practical procedures and practices for widely-applied operations and processes*

Knowledge profile

***A Washington Accord programme** provides:*	***A Sydney Accord programme** provides:*	***A Dublin Accord programme** provides:*
***WK1:** A systematic, theory-based understanding of the **natural sciences** applicable to the discipline*	***SK1:** A systematic, theory-based understanding of the **natural sciences** applicable to the sub-discipline*	***DK1:** A descriptive, formula-based understanding of the **natural sciences** applicable in a sub-*
***WK2:** Conceptually-based **mathematics**, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline*	***SK2:** Conceptually-based **mathematics**, numerical analysis, statistics and aspects of computer and information science to support analysis and use of models applicable to the sub-discipline*	***DK2:** Procedural **mathematics**, numerical analysis, statistics applicable in a sub-discipline*
***WK3:** A systematic, theory-based formulation of **engineering fundamentals** required in the engineering discipline*	***SK3:** A systematic, theory-based formulation of **engineering fundamentals** required in an accepted sub-discipline*	***DK3:** A coherent procedural formulation of **engineering fundamentals** required in an accepted sub-discipline*
***WK4:** Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.*	***SK4:** Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for an accepted sub-discipline*	***DK4:** Engineering **specialist knowledge** that provides the body of knowledge for an accepted sub-discipline*
***WK5:** Knowledge that supports **engineering design** in a practice area*	***SK5:** Knowledge that supports **engineering design** using the technologies of a practice area*	***DK5:** Knowledge that supports **engineering design** based on the techniques and procedures of a practice area*
***WK6:** Knowledge of **engineering practice** (technology) in the practice areas in the engineering discipline*	***SK6:** Knowledge of **engineering technologies** applicable in the sub-discipline*	***DK6:** Codified **practical engineering knowledge** in recognised practice area.*
***WK7: Comprehension of** the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability*	***SK7: Comprehension of** the role of technology in society and identified issues in applying engineering technology: ethics and impacts: economic, social, environmental and sustainability*	***DK7: Knowledge** of issues and approaches in engineering technician practice: ethics, financial, cultural, environmental and sustainability impacts*
***WK8:** Engagement with selected knowledge in the **research literature** of the discipline*	***SK8:** Engagement with the **technological literature** of the discipline*	
A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 4 to 5 years of study, depending on the level of students at entry.	*A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 3 to 4 years of study, depending on the level of students at entry.*	*A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 2 to 3 years of study, depending on the level of students at entry.*

Appendix 4 – Questionnaire survey to PEI staff members

Survey to Professional Engineering Institutions (PEIs)

Page 1

Thank you in advance for participating in this survey questionnaire.

Please be assured that all work will be carried out under Liverpool John Moores University's code of ethics, and the project has been approved by the university's ethics committee.

All responses given will be treated confidentially and all participants are guaranteed anonymity.

Section 1 - Personal and Institutional Details

1. Please provide the name of your Professional Engineering Institution (PEI) and the acronym by which it is normally known.

2. What is your job title? Please, very briefly, state your main roles and responsibilities.

3. Is your position with your PEI:

- Full-time salaried?
- Part-time salaried?
- Carried out on a voluntary basis?
- Other? (please specify)

3.a. If you selected Other, please specify:

4. How long have you been with your PEI in your current or similar role?

- Less than 2 years
- 2 - 5 years
- 5 - 10 years
- More than 10 years

5. Have you worked for other PEIs in a similar role in the past? If so, for how long?

- No
- Yes, less than 2 years
- Yes, 2 - 5 years
- Yes, 5 - 10 years
- Yes, more than 10 years

6. Approximately how many members does your PEI have? (If you do not have this information easily to hand, please move onto the next question.) *Optional*

6.a. How many of these members are at grades commensurate with Engineering Council registration? (i.e. CEng, IEng, EngTech, ICTTech) (Again, if you do not have these numbers easily to hand please move on to the next question.)

6.b. How many of these members are based overseas? (Again, if you do not have these numbers easily to hand please move on to the next question.)

Page 2

Section 2 – Interaction with other PEIs and with the Engineering Council

7. How often do you, representing your PEI, interact or correspond with any of the other Engineering Council licenced PEIs?

- Very regularly/daily
- Quite regularly/weekly
- Quite rarely/monthly
- Very rarely/annually
- Never

8. How often do you, representing your PEI, interact or correspond with the Engineering Council itself?

- Very regularly/daily
- Quite regularly/weekly
- Quite rarely/monthly
- Very rarely/annually
- Never

9. Please indicate your level of agreement with the following statement: "The Engineering Council represents the interests of all 35 licenced PEIs equally."

- Strongly agree
- Generally agree
- Neither agree nor disagree
- Generally disagree
- Strongly disagree
- I don't know enough about this to answer

9.a. Do you have any further view on this statement?

10. Please indicate your level of agreement with the following statement: "The Engineering Council's structure enables all engineering disciplines be represented equally."

- Strongly agree
- Generally agree
- Neither agree nor disagree
- Generally disagree
- Strongly disagree
- I don't know enough about this to answer

10.a. Do you have any further view on this statement?

Page 3

Section 3 - The UK-SPEC and entries to the UK Register of Engineers

11. Please indicate your level of agreement with the following statement about the Engineering Council publication, the UK Standard for Professional Engineering Competence (UK-SPEC): "The UK-SPEC, being the primary source of information about engineering standards and competence, is a useful and accessible publication."

- Strongly agree
- Generally agree
- Neither agree nor disagree
- Generally disagree
- Strongly disagree
- I don't know enough about this publication to answer

11.a. Do you have any further view on this statement?

12. The UK-SPEC details the professional engineering competencies that must be demonstrated by engineers wishing to be entered on the UK Register of Engineers. To what extent was your PEI involved in the process of drafting of these? (Please select the answer that best represents your view.)

- My PEI took a leading role in the process
- My PEI was involved and contributed much to the process
- My PEI was involved and contributed moderately to the process
- My PEI was involved but did not contribute much to the process
- My PEI was not at all involved in the process
- Don't know

12.a. Do you have any further views about the professional engineering competencies?

13. Please indicate your level of agreeent with the following statement:
"The professional engineering competencies published in the UK-SPEC can readily be applied to all engineering disciplines."

- Strongly agree
- Generally agree
- Neither agree nor disagree
- Generally disagree
- Strongly disagree
- I don't know enough about this publication to answer

13.a. Do you have any further view on this statement?

14. Please indicate your level of agreeent with the following statement: "The professional engineering competencies detailed in the UK-SPEC are the best way to establish competence in the engineering discipline represented by my PEI."

- Strongly agree
- Generally agree
- Neither agree nor disagree
- Generally disagree
- Strongly disagree
- I don't know of this publication
- I don't know enough about this to answer

14.a. Do you have any further view on this statement?

15. Please indicate your level of agreement with the following statement: "The Engineering Council licenced PEIs each have established procedures with which they assess applications for entry to the UK Register of Engineers - registration of engineers is therefore effected consistently and reliably by all the PEIs."

- Strongly agree
- Generally agree
- Neither agree nor disagree
- Generally disagree
- Strongly disagree
- I don't know enough about this to answer

15.a. Do you have any further view on this statement?

Page 4

Section 4 - Accreditation of Higher Education courses

16. PEIs are licenced by the Engineering Council to accredit UK Higher Education engineering courses at Masters and Bachelors level. Some do this independently, while others collaborate with other PEIs, and some are members of accrediting consortia (e.g. the Joint Board of Moderators). Please indicate the approach(es) taken by your PEI to course accreditation (please check all that apply).

- ☐ My PEI accredits engineering HE courses independently
- ☐ My PEI accredits engineering HE courses in collaboration with other PEIs
- ☐ My PEI accredits engineering HE courses as part of a consortium
- ☐ My PEI does not accredit HE engineering courses
- ☐ Don't know

16.a. Do you have any further views about course accreditation?

17. Please indicate your level of agreement with the following statement about the Engineering Council publication, Accreditation of Higher Education Programmes 3rd edition (AHEP 3). "AHEP 3, being the primary source of reference for accreditating engineering Higher Education courses, is a useful and accessible document."

- Strongly agree
- Generally agree
- Neither agree nor disagree
- Generally disagree
- Strongly disagree
- I don't know enough about this publication to answer

17.a. Do you have any further view on this statement?

18. Please indicate your level of agreeent with the following statement: "The advice and guidance given in AHEP 3 can readily be applied to HE courses in all engineering disciplines."

- Strongly agree
- Generally agree
- Neither agree nor disagree
- Generally disagree
- Strongly disagree
- I don't know enough about this publication to answer

18.a. Do you have any further view on this statement?

Page 5

Thank you!

Thank you for participating in this survey. Data collected from the survey will be quantitatively and qualitatively analysed and inferences drawn will be used in my PhD thesis, which will be submitted to Liverpool John Moores University.

Please be assured that all work will be carried out under the auspices of the univesity's code of ethics and prior ethical approval has been granted by the university.
All responses given will be treated confidentially and the anonyity of participants will be guaranteed.

If you have any questions or comments about the work or would like to read the finished thesis, please email me at D.C.King@ljmu.ac.uk

Derek King

Appendix 5 – Exploratory semi-structured interview questions

- What kind of relationship do you believe that the 35 PEIs have with the EC and with each other? Do you think generally that they work together efficiently or is there some dissonance? Are some PEIs more active and more influential than others?

- Bearing in mind that the EC represents the interests of 35 PEIs, do you consider that all members are equally influential in EC matters, and in the wider field of engineering?

- As CIBSE is a medium-sized PEI what kind of relationship do you believe it has with the EC? Do you personally have contact or regular interaction with the EC?

- Do you believe that the structure and status of the EC effectively promotes <u>all</u> engineering disciplines equally? Are some branches of engineering over-represented?

- How do you feel that the generic professional engineering competencies laid out in the UK-SPEC document fit with the requirements for MCIBSE and ACIBSE?

- How useful and accessible do you feel the UK-SPEC document is for engineers seeking to become members of the CIBSE? Do you think the UK-SPEC serves to encourage membership applications?

- Do you feel that memberships of PEIs and engineer registrations are accurately and consistently overseen by the EC? Do you feel the process is consistent across the different PEIs?

- Do you find that educational establishments generally appreciate and understand the requirements of the UK-SPEC when designing courses of study and applying for accreditation?

- With particular regard to BSE, do you believe that a UK engineering education provides graduates with an appropriate skillset when working overseas?

    a. In Washington, Sydney and Dublin Accord countries?
    b. In other EU countries?
    c. In other non WSDA countries?
    d. In the rest of the world?

- Do you feel that BSE degree courses in the UK cover the necessary specialist materials to adequately service the BSE industry? Are there enough appropriately educated BSE graduates for industry? If not, how does industry find graduates?

Appendix 6 – In-depth semi-structured interview questions

- Which BSE degree courses do you have knowledge or experience with? Was the course developed along with industrial partners and with the local CIBSE Region? Do industrial partners and the local CIBSE maintain an involvement and assist with delivery of the programme?

- How does your course satisfy the very broad curriculum requirements for BSE? Is there sufficient time and space for all essential subject matter to be delivered? Are particular BSE specialisms perhaps covered in more depth than others? In your view, are the fundamental engineering subjects (maths, science, engineering principles etc) adequately covered in the course? Are the students generally equipped to deal with all subject matter or are their difficulties in delivery?

- Please describe your experiences of developing undergraduate and post graduate study programmes to meet the requirements for professional accreditation purposes. How straightforward a process is this? How helpful is reference to AHEP 3, the UK-SPEC and the generic professional engineering competencies? How helpful is the guidance and/or support provided by CIBSE locally and/or nationally?

- Please describe your experiences of dealing with regular accreditation visits from CIBSE. Have you been involved in accreditation applications/visits with other PEIs? How do these compare with the CIBSE approach? Do you feel that professional accreditations are accurately and consistently overseen by the EC? Do you believe the process is consistent across the different PEIs?

- Do you feel that the requirements for engineer registration are fair and achievable for graduates from your course? How useful and accessible do you feel the UK-SPEC document is for engineers seeking to become members of the CIBSE and EC registrants? Do you think the UK-SPEC serves to encourage membership applications?

- What is your view on international transparency and mutual recognition of engineering qualifications? Do you think the WSDA agreements constitute a useful and beneficial contribution? Do you think that the EUR-ACE system provides a useful and beneficial contribution? Are there other international agreements of which you are aware?

- Are you aware of graduates from your course going on to practice in other countries? Which countries are common destinations? Do you believe that a UK BSE education provides graduates with a good skillset when working overseas?

    a. In Washington, Sydney and Dublin Accord countries?
    b. In EU countries?
    c. In the rest of the world?

- Is there anything in UK BSE education & training system that gives UK graduates an edge? If you were designing an education & training system to facilitate overseas opportunities for UK graduates is there anything that is not currently included that should be included? Is there anything that could be done better?

Appendix 7 – Concluding semi-structured interview questions

- What do you like about the model and what do you not like?
- How do you feel about the principle of work based learning running concurrently with higher education? Do you feel that this model could be workable for employers?
- Do you believe the academic content of the model is correct and well-founded?
- Do you believe that the structure of the work based training course is correct and well-founded?
- How do you feel about the idea of a year of the training programme being delivered overseas?
- Do you believe that this model could improve international prospects for UK BSEs?
- Do you believe that this model could be exported overseas?