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Challenges in delivering the UK-SPEC learning outcomes in engineering

A non-Russell Group sector experience

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Abstract

According to the UK- SPEC, a key competence practicing engineers at CEng and IEng levels are expected to demonstrate is: *the theoretical knowledge to solve problems in developed/new technologies, and the ability to use analytical techniques to solve problems*. This discussion paper is aimed at drawing attention to some of the key issues and challenges that we, the engineering teachers, face in delivering the curriculum to achieve the required objective in the context of satisfying the aspirations of key stake holders, viz. the students, PSRBs and the engineering industry.

Our approach recognises that building upon a solid foundation of knowledge and understanding of core engineering principles and concepts is essential to further learning and continuity of progress. Based on this platform, gradual development of students' critical thinking and analytical ability to solve real engineering problems is the key to their future success towards innovation and progress as a practicing engineer. Thus balancing the curriculum delivery strategy to progressively build up this confidence at different stages within the core discipline specific subjects is crucial rather than attempting to superficially manage student expectations and course rankings.

Some examples of good practice and ideas for change based on the presenters' experience in teaching students of different background mathematical and analytical ability levels, at the SHU and other institutions across the national and international HE sector, will be presented to catalyse thinking. The importance of adopting appropriate and relevant strategies at different levels across the programmes will be discussed. Attention will be drawn to the use of state-of-the-art analytical software to enhance student learning experience and thereby develop valuable engineering skills, and also examples of effective use of project studies to develop a multitude of problem solving skills.

The paper also aims to address apparent confusion that seems to exist between developing transferable skills as opposed to developing competence to practice the engineering profession.

Why have we selected this topic?

We thought it is timely to draw attention to what really contributes to the identity of an engineering degree programme and some of the complexities associated with its delivery to satisfy stake holder aspirations. The student, and the profession for which they are being trained, occupy the centre stage in any discussion. The focus is to deliver a programme which builds up self-confidence in the individual to practice the profession in a rapidly changing technological scenario with continued career progression, whilst contributing effectively to development and innovation in the engineering profession. Towards this, the knowledge base acquired in the specific discipline and related areas are of primary importance.

What are knowledge, understanding, know-how and skills?

According to Engineering Council interpretations as exemplified in the engineering degree accreditation documents, **knowledge** is information that can be recalled whereas **understanding** is the capacity to use the knowledge creatively, for example in problem solving, design, explanations and diagnosis. **Skills** on the other hand are acquired and learned attributes that can be applied almost automatically. **Know-how** appears to be a combination of all the above in that it is defined as the ability to apply learned knowledge and skills to perform operations intuitively, efficiently and correctly.

So what then are the **transferable skills**? These are somewhat a mix of certain subject specific skills as well as the general abilities a student develops during a programme of study that will be of value in a wide range of situations. They might be technical or general, and include skills such as problem solving, communication, working with others, information retrieval, effective use of IT, exercise initiative and personal responsibility as a team member or leader, monitor and adjust a personal programme of work on an on-going basis, and plan self-learning and improve performance as the foundation for lifelong learning/CPD.

It is clear that there is much room for overlap and confusion in the interpretation and use of these different terms. The academic staff are often faced with this dilemma and some may be tempted to follow a path of personal preference within their own comfort zone in the delivery due to ignorance or, in some instances, callous disregard to the broader expectations of a programme (i.e. programme learning outcomes), its intended academic depth and breadth and its intellectual rigour. It is the degree accreditation process which identifies (or at least expected to identify through evidence submitted) these short comings in implementation, but it is also possible some unsound practices may go unnoticed. Whilst regulatory mechanisms are in place, what is most important is for the staff to be well informed about these complexities and not to compromise on the academic quality of the overall programme for short-term gain or superficial rankings. Rather than individual preferences, the long-term sustainability of a programme and the institution's reputation as a leading provider of engineering education in the UK should be the primary drivers for programme change.

Regulation of the Engineering Profession and Academic Standards

The Engineering Council (EC) as the UK regulatory body for the engineering profession sets and maintains the internationally recognised standards of professional competence and ethics that govern the award and retention of the titles, Chartered Engineers (CEng), Incorporated Engineers (IEng), Engineering Technicians (EngTech) etc. The *Quality Assurance Agency (QAA) Subject Benchmark Statement for Engineering* sets out threshold academic standards that all providers of UK engineering higher education reviewed by the QAA should ensure.

Since 2006, the engineering community has agreed that the academic standards expected of engineering graduates are the same as the learning outcomes for graduates of Engineering Council accredited degrees, as set out in the *Accreditation of Higher Education Programmes: UK Standard for Professional Engineering Competence (AHEP)*. For this reason a separate list of standards is not provided in the Benchmark Statement. In producing the most recent (February 2015) version of the subject benchmark statement, the QAA has worked closely with the EC to ensure that the statement takes account of the review and revision of the *Accreditation of Higher Education Programmes: UK Standard for Professional Engineering Competence* which was completed in May 2014 *(AHEP3)*. This approach enables engineering higher education providers to work from a single point of reference to meet academic and professional standards, thereby minimising the danger of conflicting interpretations, either by higher education providers or accrediting agencies.

The UK-SPEC and Degree Accreditation

How does the Engineering Council ensure uniformity of professional standards across the Engineering Institutions?

The *United Kingdom Standard for Professional Engineering Competence (UK-SPEC)* sets out the required competence levels for registration as a Chartered Engineer (CEng) or an Incorporated Engineer (IEng). The professional engineering institutions which are licensed by the Engineering Council for degree accreditation have adopted the **competence statements** in the UK-SPEC as the reference point for in determining whether a programme is delivering knowledge, understanding and skills at the appropriate level. **Competence** is explained 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 professional attitude".

In the context of this paper and according to the UK- SPEC, a key competence practicing engineers at CEng and IEng levels are expected to demonstrate is the theoretical knowledge to solve problems in developed/new technologies, and the ability to use analytical techniques to solve problems. These are exemplified in the UK-SPEC primarily under the **'Specific Learning Outcomes'** categories US and E.

- **Underpinning Science and Mathematics** and associated engineering disciplines **(US)**
- **Engineering Analysis (E)**

As already stated, the EC sets the overall requirements for the Accreditation of Higher Education Programmes in engineering (AHEP) in line with the UK-SPEC. AHEP was first published by the Engineering Council in 2004, and adopts the same outcomes-focused approach as UK-SPEC. It was reviewed in 2013 with its latest (third) edition published in May 2014 (AHEP3). In this latest version what were previously referred to as **'General Learning Outcomes'** have mostly been integrated within the five engineering-specific areas of learning, except for some that are listed as **'additional general skills'**, which are primarily transferable skills additional to those incorporated within the other learning outcomes.

Thus the realigned six **'key areas of learning'** in the AHEP3 are:

- Science and mathematics
- Engineering analysis
- Design
- Economic, legal, social, ethical and environmental context
- Engineering practice
- Additional general skills

The thrust of this paper is on the first two.

Our approach to programme design and delivery

Our approach is simply recognition of what is expected in the key controlling documents (as clarified above) and designing the programme and planning its delivery at different stages to realise the objective. However, in doing so, there are key challenges we as engineering teachers face and have to overcome, the first and foremost being the widely differing standards of fundamental knowledge in mathematics and physics within the same cohort of students.

We believe that building upon a solid foundation of knowledge and understanding of core engineering principles and concepts is essential to further learning and continuity of progress. Based on this platform, gradual development of students' critical thinking and analytical ability to solve real engineering problems is the key to their future success towards innovation and progress as a practicing engineer. Thus balancing the curriculum delivery strategy to progressively build up this confidence at different stages within the core discipline specific subjects is crucial rather than attempting to superficially manage student expectations and course rankings.

The approach is summarised as:

Level 4 - A sound platform to build upon for subsequent years

- Strong focus on reinforcing **fundamental knowledge**.
- Engineering **principles and concepts**.
- Analytical approaches to **problem solving**

Level 5 - Subject specific engineering skills development

- Development of **critical thinking** and **analytical ability**.
- Use of state-of-the-art **analytical software tools**.
- **Project based learning.**

Placement year - Broadening Horizons

Level 6 - Further development of higher level engineering skills and build up motivation to progress up to MEng. level.

- **state-of-the-art software** skills.
- **Intellectual challenge**.
- Innovation in Engineering and the **Project**.

Level 7 - Leadership development and **interdisciplinary study**/group project focus.

This approach recognises that offering strong MEng degrees and the majority of students opting to continue on this path beyond the BEng level are essential for long-term sustainability and enhancing reputation of our key engineering programmes.

Underpinning Science and Mathematics (US) / Engineering Analysis (E)

As an example, the UK-SPEC specific learning outcome US2m states: *A comprehensive knowledge and understanding of the mathematical models relevant to the mechanical and related engineering disciplines and an appreciation of their limitations.*

Consider a familiar example in engineering. Students study about materials deforming under forces (loads), the deformation characteristics of different classes of materials, their strength and failure modes. To understand such phenomena clearly and to facilitate analytical interpretation, the basic concepts of stress and strain are introduced at a very early stage in a programme. Students quickly become familiar with the stress-strain curve, their understanding of the topic often supported by a simple laboratory test performed on a tensile test machine under uniaxial loading conditions, and are able to compare between material classes on this basis. They are able to appreciate, understand and distinguish between the terms yield strength, proof stress, tensile strength, fracture strength etc.

This study of stresses and strains is extended to other loading situations such as simple bending of straight beams (simple structural members), torsion of circular shafts and then to more complex problems such as a propeller shaft where different types of loads act in combination. As the problems become more complex, so does the theoretical analysis. At the next level of study, the concept of 'principal stresses' is introduced together with the graphical approach of Mohr's stress circle. To facilitate the prediction of failure under three dimensional stresses on the basis of already familiar (uniaxial) yield strength, 'yield criteria' are then introduced. Soon the student is faced with the problem of designing real components in engineering systems under complex, combined loading and at this stage begins to appreciate the scope and limitations of the pen and paper approaches and tedious calculation procedures in solving complex structural problems. Supported by the background mathematical knowledge developed in parallel modules, students are now in a position to appreciate and understand the theory behind finite element analysis and effectively use state-of-the-art FEA software to solve complex engineering problems and critically analyse the results. By this stage they have more or less developed expertise to approach a complex problem with confidence with a logical approach.

The UK-SPEC specific learning outcome E3m states: '*An understanding of the capabilities of computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases'* as a key learning outcome at MEng level. There are numerous examples in an engineering curriculum, such as the one explained above, where the UK-SPEC key learning outcomes can be effectively addressed by intuitive course design and delivery strategies.

References

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