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ADDRESSING THE UK-SPEC COMPETENCE LEVELS: CHALLENGES IN PROGRAMME DESIGN AND DELIVERY IN A DIVERSIFYING ENGINEERING HE SECTOR

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Abstract: The UK-SPEC describes the respective competence levels that have to be met for professional registration as an Engineer or an Engineering Technician. At the level of Engineer, a further demarcation between competence levels, often less understood by the academic community, is in the designations Chartered Engineer and Incorporated Engineer. The UK-SPEC clearly sets out criteria which distinguish between the two categories. Background academic training plays an important part in the pathways leading to professional registration, and although not binding, academic qualifications that exemplify the required levels of knowledge and understanding for CEng and IEng registration are explicitly stated in the UK-SPEC. Higher level qualifications are the prime focus of HE sector engineering education providers as well as their clients, i.e. the students, in the context of a highly competitive recruitment setting.

This paper recognises that 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 intelligent curriculum design and imaginative delivery strategies are crucial to progressively build up confidence through core engineering subjects. The study draws attention to examples of effective use of state-of-the-art analytical software to enhance student learning experience and thereby develop valuable subject specific skills, and the use of project studies to develop a multitude of problem solving and transferable skills.

Keywords; UK-SPEC, competence levels, curriculum design, subject specific skills, transferable skills, computer simulations

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1. INTRODUCTION

1.1 Engineering Competence

Competency is regarded as an underlying characteristic of an individual which enables them to deliver superior performance in a given context. Competence to practice a profession at a defined level is acquired through the systematic development of knowledge, attitude and a skill set during a preliminary phase of carefully designed rigorous training, usually regulated and monitored by the 'professional bodies'.

The UK Standard for Professional Engineering Competence (UK- SPEC) (Engineering Council, 2014a) describes the requirements that have to be met for professional registration in order to practice the engineering profession at a defined level. According to the UK-SPEC, a key competence practicing engineers at Incorporated Engineer (IEng) level are expected to demonstrate is the theoretical knowledge to solve problems in developed technologies using well proven analytical techniques, whereas at Chartered Engineer (CEng) level this is a step further in that it is the theoretical knowledge to solve problems in new technologies and develop new analytical techniques. As emphasised in the UK-SPEC, continuing professional development (CPD) is understood as the systematic acquisition of knowledge and skills, and the development of personal qualities, to maintain and enhance professional competence. Thus at CEng level, the depth and breadth of academic training is expected to be pitched at an appropriate level to facilitate CPD of chartered engineers to naturally take place during their professional career, enabling them to lead the profession exercising knowledgeable judgement.

1.2 Academic Standards

The academic institutions have a primary responsibility to facilitate knowledge and skill acquisition at the appropriate levels commensurate with the learning programme titles they promote in recruiting students. This is a very challenging scenario for the academics involved with engineering programme design, and it requires considerable foresight and in depth understanding of the specific engineering discipline they are involved with.

The problem is compounded by the widely varying entry qualifications and academic standards among the entry cohorts. Student recruitment has become highly competitive in recent times, so much so that entry standards seem to be a lesser priority. A significant proportion of fresher students lack the pre-requisite knowledge in fundamental mathematics and physics which is essential to their progress in engineering studies, and it is a fallacy to assume that such base knowledge can be effectively acquired / imparted during the first year of studies. A BEng (Hons) degree programme has only three years of academic study compared to counterpart programmes such as degrees in medicine, and to teach subject matter which should have been gradually developed at secondary school level is a waste of time and resources. Unless this situation is correctly understood and carefully managed by programme directors, and sensitively handled by the academics at class room level and in assessment, a majority of students with the pre-requisite background knowledge lose the opportunity of acquiring further knowledge with the danger of complacency setting in without any deep learning taking place. It is a path of 'strategic learning' (Higher Education Academy, 2005) that we promote in this paper which will lead to acceptable grades of achievement for the majority of learners, whilst indirectly promoting facets of deep learning and rewarding those learners who deserve recognition.

This paper is aimed at drawing attention to some of the key issues and challenges that the engineering teachers face in delivering the curriculum to achieve the required objective while satisfying the aspirations of key stake holders, viz. the students, PSRBs (Professional, Statutory and Regulatory Body) and the engineering industry.

2. ENGINEERING PROFESSION

The profession for which a student is being trained must occupy the centre stage in any discussion on academic matters. The focus shall be to deliver an engineering study programme which builds up self-confidence in the individual to practice the profession in a rapidly changing technological scenario with uninterrupted career progression, whilst contributing effectively to development and innovation in engineering. Towards this, the advanced knowledge acquired in the specific discipline and related areas are of primary importance.

2.1 Regulatory bodies

The Engineering Council (EC) as the UK regulatory body for the engineering profession sets and maintains internationally recognised standards of professional competence and ethics that govern the award and retention of the titles, Chartered Engineer (CEng), Incorporated Engineer (IEng) and Engineering Technician (EngTech). The Engineering Accreditation Board (EAB) administered by the Engineering council is made up of all the professional engineering institutions (PEIs) that are licensed by the Engineering Council to accredit academic programmes for both Incorporated Engineer and Chartered Engineer status.

The Quality Assurance Agency for Higher Education (QAA) through its Subject Benchmark Statement for Engineering (QAA, 2015) sets out threshold academic standards (QAA, 2008) that all providers of UK engineering higher education reviewed by the QAA should ensure. The Royal Academy of Engineering provides overall leadership and promotes excellence across all fields of engineering to the benefit of society, and together with learned forums such as the Engineering Professors' Council (EPC), has an overarching role in shaping engineering education in the UK.

2.2 Regulation of Academic Standards

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 QAA Subject Benchmark Statement for Engineering. In producing the most recent version of the subject benchmark statement (QAA, 2015), 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 (AHEP3) (Engineering Council, 2014b). This approach has enabled 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.

3. DEGREE ACCREDITATION

3.1 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 **transferable skills**? These are somewhat a complex 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 (Engineering Council, 2014b). 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 in programme specifications. For example, learning a computer skill to solve a complex engineering problem can be misinterpreted as understanding a challenging analytical academic topic. The academic staff are often faced with this dilemma and some may unknowingly follow a path of personal misapprehension controlled by the limits of their own understanding of subject boundaries. The broader expectations of a programme, i.e. programme learning outcomes, are thereby jeopardised, the intended academic depth and breadth and its intellectual rigour compromised with serious repercussions on the quality of graduates produced. It is the degree accreditation process more than the internal quality and revalidation processes which are able to identify these short comings through evidence submitted, but it is possible that some unsound practices may go unnoticed. Whilst regulatory mechanisms are necessary, what is most important is for the staff to be well informed about these complexities and not to compromise on the academic quality of an overall programme for superficial rankings. The long-term sustainability of a programme and safeguarding an institution's reputation as a leading provider of engineering education should be the primary drivers for programme change. This process must be led by experienced academics with an overarching knowledge of the field.

3.2 PEIs and the EAB

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 determining whether a programme is delivering knowledge, understanding and skills at the appropriate level. The aim of the EAB (*Section 2.1*) is to encourage consistent accreditation processes and practices as well as to provide a single point of contact to facilitate joint accreditation visits; EAB visits are intended for those HEIs seeking the accreditation of either mixed discipline degrees or a range of engineering courses by a number of PEIs.

The document Accreditation of Higher Education Programmes, first published by the Engineering Council in 2004, adopts the same outcomes-focused approach as the UK-SPEC. It was reviewed in 2013 with its third edition published in 2014 (Engineering Council, 2014b). 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 a few that are listed as 'additional general skills'. These 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 (SM), Engineering analysis (EA), Design (D), Economic, legal, social, ethical and environmental context (EL), Engineering practice (P) and Additional general skills (G).

In seeking accreditation including delivery for September 2016 or beyond, educational institutions must demonstrate alignment of programme learning outcomes with the revised AHEP3. The focus of this paper is on the learning outcome categories Science and Mathematics (SM) and Engineering Analysis (EA) as specified in the EAB’s Output Standards Matrix based on AHEP3 (Engineering Accreditation Board, 2016).

4. OUR APPROACH

4.1 Strategy

The authors’ approach is simply recognition of what is stipulated in the key controlling documents as clarified above, and designing a 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. The words ‘fundamental knowledge’ is emphasised here to distinguish it from ‘higher level knowledge’.

The authors strongly 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 high level performance as a practicing engineer. Therefore, 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.

4.1 Action Plan

The following 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 key engineering programmes.

Level 4 studies (First Year of MEng/BEng programme): The learning objective at this level is to build up a powerful knowledge base of key engineering principles and concepts upon which learning in subsequent years would be developed. There is a strong focus on reinforcing fundamental knowledge and systematically developing analytical approaches to problem solving.

Level 5 studies (Second Year of MEng/BEng programme): Subject specific engineering skill development is a key learning objective at this level. Analytical ability is further developed together with critical thinking in solving complex problems. Project based learning is promoted at this level.

Industry Placement (Third Year of MEng/BEng sandwich programme): Broadening Horizons. Although not mandatory, sandwich year is promoted among all students for its wide ranging academic benefits, apart from the employability perspective.

Level 6 studies (Fourth Year of MEng/BEng sandwich programme): Intellectual challenge**.** Further development of higher level engineering skills and the effective use of state-of-the-art analytical software tools. Developing ability to apply quantitative and computational methods using alternative approaches, and understanding their limitations. Individual Project and build up motivation to progress to MEng level.

Level 7 studies (Fifth Year of MEng sandwich programme): Leadership development and interdisciplinary study focus; innovation in engineering through Group Project.

5. CASE STUDIES

5.2 Science and Mathematics (SM)

CEng level learning outcome 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”.

EAB Output Standards Matrix (AHEP 3rd Edition)

In a familiar example in engineering, students study the deformation characteristic of materials under load, their strength and failure modes. To facilitate analytical interpretation, the concepts of stress and strain are introduced at a very early stage. Students quickly become familiar with the stress-strain curve, their understanding of the topic supported by a simple laboratory test performed on a tensile test machine under uniaxial loading conditions. Through a comprehensive mechanical testing programme, students learn to compare the mechanical behaviour between different classes of materials and are able to appreciate, understand and distinguish between the terms yield strength, proof stress, tensile strength, fracture strength etc.

At the next stage, the study of stresses and strains is extended to loading situations such as simple bending of structural members, torsion of circular shafts and then to more complex problems such as propeller shafts 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 concepts of 'stress transformation' and ‘principal stresses’ are introduced together with the graphical approach of Mohr's stress circle. To facilitate the analysis of structural failure under three dimensional stresses on the basis of already familiar (uniaxial) yield strength, ‘yield criteria’ are introduced. To support the learning and address different learning styles, a series of stimulating laboratory experiences are embedded, for example strain rosette analysis leading to 'von Mises stress' calculations and, crack growth and fracture toughness measurement. Soon the students are faced with the challenge of designing real components in engineering systems under complex loading, and begin 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, the learners are now in a position to appreciate and understand the theory behind finite element analysis, effectively use state-of-the-art FEA software to solve complex engineering problems and critically analyse the results. They have also developed the ability to identify the limitations of quantitative and computational methods. Developing the expertise to systematically solve a complex engineering problem with confidence and a logical approach is higher level training.

5.3 Engineering Analysis (EA)

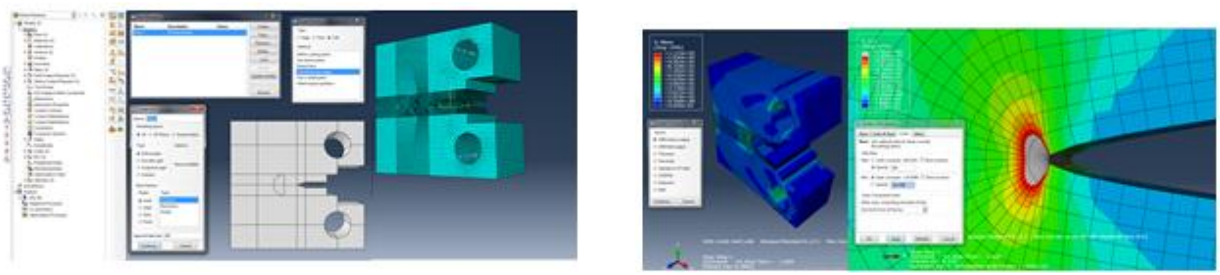
CEng level learning outcome EA2:

“Ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques”.

EAB Output Standards Matrix (AHEP 3rd Edition)

This case study relates to a learning - teaching plan in structural analysis and FEA, involving a cohort of MEng level 7 learners and implemented over a period of three months. The key focus and driver for knowledge acquisition on the part of the learners is a comprehensive summative assignment worth 50% of the module mark. The assignment fully addressed the key module learning outcomes in keeping with principles of constructive alignment (Biggs, 2005). The associated knowledge dissemination and support sessions were designed adhering to the principles of 'flipped classroom' instructional strategy (O'Flaherty and Phillips, 2015). This approach intentionally shifts instruction to a learner-centered model, thereby allowing classroom contact time to be used more efficiently to explore topics in greater depth. Student-centred and tutor-centred approaches both have their own value, and bring variety to the learning process (Tittagala et al., 2008).

The task was presented in two parts: a fracture toughness test performed in the laboratory on a standard compact tension test specimen with controlled displacement test procedure conforming to BS/ASTM standards preceded the subsequent finite element analysis simulating the test. The software used for the task was ABAQUS/CAE. Using one 2-D and one 3-D modelling approach of choice, the learners were required to proceed with the different phases of creating a refined FEA model to perform analysis (Figure 1). The purpose of this analysis was to show the consistency of theoretical, experimental and numerical results and the validity of the different methods. The analysis was extended to the elastic-plastic zone at the crack tip for comparison with results from calculations.



(a) (b)

Figure 1 (a) Design and Modelling, and (b) Analysis phases of compact tension fracture toughness test specimen in FEA assignment.

The flipped materials included interactive "How to ……" tutorials, replacing the full version of the user manual to practice and familiarise with the FEA software at the initial stages. The learners essentially needed to learn and practice using the tool to be able to successfully progress with the coursework and complete the summative task. The class room contact time was used efficiently and the task completed on time with good quality. Extensive peer support during sessions was evident and the learning outcomes were effectively met. Overall, the level of achievement significantly improved and learner engagement with the task was excellent. Ability to apply quantitative and computational methods and understanding their limitations is a key competence to be developed at MEng level.

6. CONCLUSION

There is space and opportunity in a logically designed engineering curriculum to effectively address the key learning outcomes specified in AHEP3 through systematic and efficient delivery strategies. In all instances, developing competence in the learners to practice the engineering profession at a defined level, CEng or IEng, should be the foremost responsibility of higher education providers. Learner and institutional expectations should be managed strictly within this framework so that the quality of output is not compromised.

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