The Influence of Outcomes Based Accreditation Criteria of Engineering Council UK on Engineering Education in Northumbria University and International Collaborative Academic Institutions

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Abstract

This decade witnesses an increased level of convergence of engineering education and in the mutual recognition of accredited engineering degree programmes due in part to the proliferation of outcome based engineering education. Outcome based engineering education focuses on outputs through achievements of learning outcomes instead of inputs and processes. Articulation of learning outcomes and demonstration of achievements of these learning outcomes are therefore vitally important for accreditation of degree programmes that are increasing accredited by the outcome based approach. The influence, mainly in degree programmes articulation of learning outcomes and their achievements, of this approach to accreditation of engineering degree programmes in the U.K. in general, and in Northumbria University and its international collaborative academic institutions, are described in this paper.

Introduction

This decade sees an increase level of global convergence of engineering education and the emergence and proliferation of outcome based engineering education. Accredited engineering degree programmes in one country can now enjoy increasing mutual recognitions from universities, institutions and professional bodies from a number of countries. This paper briefly describes the global convergence of engineering education; the outcome based accreditation approach and relates to the learning outcomes based accreditation requirements of Engineering Council U. K. (ECUK) which is carried out by appropriate professional bodies such as the Institution of Mechanical Engineers (IMechE). The influence of this relatively new approach to accreditation to mechanical engineering degree programmes is mainly on the articulation of achievements of learning outcomes of the output cohorts in accreditation and degree programme documentations which is a shift from the previous emphasis on articulation of inputs and processes. Some details of such a change in accreditation of Northumbria University mechanical engineering programmes and the effects of such a shift in focus on international collaborative academic institutions are then described.

Convergence of Global Engineering Education

Over the last decade the development of engineering education is one of convergence, in part due to globalisation which increases the demands for an internationally recognised engineering profession, and in part due to the convergent development of approach towards engineering education. Hence mutual recognitions of academic qualifications and professional competency in various engineering disciplines are encouraged (Phillips et al. 2000). The developments of mutual recognitions and unification of engineering education approaches are exemplified by the International Engineering Agreements and the Bologna process.

The International Engineering Alliance promotes mutual recognition of engineering education and professional practices through international engineering agreements. The recognitions of engineering academic qualifications from universities are expressed by: (a) the Washington Accord, (b) the Sydney Accord and (c) the Dublin Accord covering accredited engineering degree programmes from universities and institutions in most continents. The accredited degree programmes are mutually recognised by participating signatories. For example, the Washington Accord's signatories include Australia, Canada, Taipei, Hong Kong, Ireland, Japan, Korea, New Zealand, Singapore, South Africa, the United Kingdom and the United States of America (IEA 2009). There are a certain levels of overlaps in that some countries are signatories of more than one accord. For example, all the three accords include the United Kingdom as one of their signatories. The responsibilities of accreditation for participating countries of these accords fall on respective recognised bodies. For example, in the U.K. the accreditation body is (ECUK), in the U.S. the accreditation body is the Accreditation Board for Engineering and Technology (ABET) and in Korea the accreditation body is Accreditation Board Engineering Education Korea (ABEEK). The Bologna process is an European Union (EU) initiative which aims to create an European Higher Education Area (EHEA) of mutually recognised academic qualification within the EU by 2010 (Bologna 2009) based on national frameworks and an overarching framework of qualifications within the EHEA (Bologna 2007).

An important common element in the convergence of global engineering education is the proliferation of outcome based approach to engineering education which replaced the earlier approach which focused on inputs and processes. This approach is related to the idea of constructive alignment which aligns teaching/learning activities and assessments to a set of well defined learning outcomes (Biggs, 1999). Outcomes base engineering education focuses on outputs and threshold standards of engineering degree programmes. Defining a set of learning outcomes for degree programmes and associated modules with threshold standards ensure competency of graduates in meeting the requirements of engineering education as defined by the various national accreditation bodies (Aziz et al. 2005, Bologna 2006, Tavner 2005).

The Engineering Council UK (responsible for the registration of UK chartered engineers in the U.K.) formalised the accreditation criteria for academic degree courses leading to Chartered Engineer status with the publication of UK-SPEC. (U.K. Standard for Professional Engineering Competence) in 2004 (ECUK 2008) which specifies the requirements of education base and professional competency for a Chartered Engineer. The emphasis of UK-SPEC education base is on meeting standards (threshold standards) and outcomes i.e. on meeting all outcomes based criteria, which differs from the previous superseded criteria which focused on the specification of inputs (i.e. students joining the academic degree courses in engineering) and processes. In the U.K., the education base (i.e. academic requirement) for a Chartered Engineer is either a three-year Bachelor of Engineering (Honours) (BEng (Hons) degree with an appropriate one-year Master level qualification or a four-year Master of Engineering (Honours) (MEng (Hons)) degree. The emergence of learning outcome based accreditation criteria also represents a convergence of various bodies involved in the U.K. higher education such as Quality Assurance Agency (QAA) engineering benchmark criteria for engineering degree courses (QAA 2006).

The increased collaborations between universities from different countries in the provision of engineering education requires due considerations in the accreditation process. Within the U.K., ECUK allows degree programmes that has an element of exchange (e.g. a year in universities in Europe or North America) or has an element of franchise (i.e. the degree programme is 'owned' by a U.K. university but delivered in a partner institution in a different country) to be considered for accreditation.

Demonstration of Achievements of Learning Outcomes: Accreditation of Mechanical Engineering Degree Programmes at Northumbria University

Although the accreditation criteria are set by ECUK the accreditation process is dealt with by appropriate professional bodies such as IMechE for mechanical engineering related degree programmes. The education base of IMechE specifies a set of General Learning Outcomes and a set of Specific Learning Outcomes. Accreditation of engineering degree programmes are therefore based on satisfaction of these learning outcomes (IMechE 2005). The university seeking accreditation is required to demonstrate how these learning outcomes are achieved including appropriate assessments and definition of threshold standards. In principle, the outcome based accreditation should not require redesigning of a sound degree programme but in practice it often requires specific articulation in programme documentation to demonstrate the achievements of specified learning outcomes.

Northumbria University has successfully obtained the maximum five year accreditation for CEng for BEng (Hons) Mechanical Engineering and MSc Mechanical Engineering programmes. The outcome based approach to accreditation in this case requires specific articulations, which will be briefly described by some examples in changes in programme documentations of BEng. (Hons) Mechanical Engineering programme in order to demonstrate the achievements of these learning outcomes.

The UK-SPEC specific learning outcomes for the accreditation of BEng. (Hons) programmes for CEng education base are grouped into five themes each of which are further elaborated with actual learning outcomes required. The main themes and some of the specific learning outcomes of these themes are shown below:

1. Underpinning science, mathematics, and associated engineering disciplines (US)
   a. US1: knowledge and understanding of scientific principles and methodology.
   b. US2: knowledge and understanding of mathematical principles.
   c. US3: ability to apply and integrate knowledge and understanding of other engineering disciplines.
2. Engineering Analysis (E)
   a. E1: understanding of engineering principles and the ability to apply them to analyse key engineering processes.
   b. E2: ability to identify, classify and describe the performance of systems and components through analysis methods and modeling techniques.
   c. E3: ability to apply quantitative methods and computer software to solve engineering problems.
   d. E4: understanding of and ability to apply systems approach to engineering problems.
3. Design (D): D1 – D6
4. Economic, social and environmental context (S)
   a. S1: knowledge and understanding of commercial and economic context of engineering process.
   b. S2: knowledge of management techniques which may be used to achieve engineering objectives.
   c. S3: understanding of the requirement for engineering activities to promote sustainable development.
   d. S4: awareness of framework of relevant legal requirements governing activities including personnel, health and safety, and risk issues.
   e. S5: engineering ethics.
5. Engineering practice (P): P1 – P8.

A summary matrix is required to show the achievements of these learning outcomes from all the core and optional modules within the specific programme under consideration for accreditation. It should be noted that to have built-in robustness and redundancy, each learning outcome should have multiple routes (from different modules and different levels). The learning outcomes sections of the module documentations were amended so to align the learning outcomes of specific modules to those of UK-SPEC. An example of the matrix is shown in Table 2.

Assessment of Learning Outcomes

The articulated learning outcomes specified in the matrix are then constructively aligned with the articulation of the learning outcomes of the module descriptors and with appropriate assessment strategy. For a specific module within the programme, usually no more than six learning outcomes are recommended as these must be aligned to appropriate assessment strategy. The process of aligning learning outcomes of the first year module "Engineering Mechanics" is shown here for illustrative purpose. The articulation of learning outcomes of this module, which has been revised to meet UK-SPEC requirement is shown in Table 1. The articulation of learning outcomes of this module is aligned to the summary matrix shown in Table 2, which for illustrative purpose shows only a part of the actual table. Note that the learning outcomes are articulated in UK-SPEC terms which tend to be more generic than the usual articulation of learning outcomes.

Table 1: Learning Outcomes of First Year Module "Engineering Mechanics"

1. To understand and apply scientific principles and methodology to analyse internal, external forces. (related to US1)
2. Applying mathematical principles to analyse systems of static and dynamic forces. (related to US2)
3. To understand engineering principles to analyse the effect of forces and moments on the motion of a body (related to E1)
4. To manage design process by performing appropriate design calculations and evaluating the outcomes. (D6)
5. Engineering laboratory skills (P2)

Table 2: An Example Summary of UK-SPEC Learning Outcomes

THE SUMMARY OF UK-SPEC SPECIFIC LEARNING OL

Programme Title BEng(H): Mechanical Engineering

YEAR	COURSES		Level	Assessment Method	US1	US2	US3	E1	E2	E3	E4	D1	D2
YEAR 1	Introductory Mechanics	EN0100	4	15% Class test, 15% Lab, 70% Exam	✓	✓		✓					
	Energy and the Environment	EN0101	4	15% Class test, 15% Lab, 70% Exam	✓			✓	✓			✓	
	Design and Computing Skills	EN0103	4	100% CW							✓	✓	✓
	Materials and Manufacture	EN0146	4	15% Class test, 15% Lab, 70% Exam	✓								
	Communications Skills and Experimental Study	EN0151	4	100% CW	✓			✓					
	Engineering Mathematics	MS0265	4	25% CW, 75% Exam		✓			✓				
YEAR 2	Applied Mechanics	EN0200	5	15% CW, 15% Lab, 70% Exam	✓	✓			✓		✓		
	Energy Conversion Systems	EN0201	5	15% CW, 15% Lab, 70% Exam	✓	✓		✓	✓				
	Computer Modelling and Design	EN0204	5	100% CW						✓	✓	✓	
	Business of Manufacture	EN0205	5	20% Lab, 80% Exam							✓		
	Further Engineering Mathematics	MS0264	5	100% exam		✓			✓	✓			
	Professional Development	CM0501	5	100% CW									
	Instrumentation, Electrioncs and Industrial Control	EN0557	5	100% exam	✓				✓				

To demonstrate the achievements of these specified learning outcomes, an appropriate assessment strategy is required. With the proliferation of outcome based engineering education, appropriate assessment of learning outcomes has been discussed and various assessment methods/strategies have been proposed (HEA 2005, Deng et al. 2003). It is clear from a conventional assessment strategy (e.g. examination 70%, laboratory work 15%, test 15%) is unable to demonstrate the achievements of the learning outcomes. However, since virtually all universities in the U.K. relies on this conventional assessment approach for the purpose of assigning numerical marks for the modules the average of which is used to determine progression from one year of study to another or the classification of the degree.

An appropriate assessment strategy in accordance to HEA recommendation to demonstrate the attainment of a subset of learning outcomes, US1, can be demonstrated by Test (T) and Examination (E) through the mapping shown in Table 3. Note that this strategy allows one to link the more generic learning outcomes to specific topics within the module and to demonstrate the achievements of these learning outcomes. It also allows the conventional assessment approach "run in parallel".

Table 3: An Appropriate Assessment Strategy for US1

“Engineering Mechanics” Year One

The student should demonstrate the ability to:

1. Resolve forces (T, E)
2. Draw free body diagrams (T, E)
3. Calculate simple stresses (T, E)
4. Determine reaction forces/moments for statically determinate cases (T, E)
5. Draw SF and BM diagrams (T, E)
6. Determine bending stresses of statically determinate beams (T,E)
7. Calculate torsional stresses (T, E)

(T: Test, E: Exam)

Satisfying all	7 criteria	very good
	6 criteria	good
	5 criteria	satisfactory (threshold) corresponding to 40 mark
	4 criteria	below average
	3 or less	poor

For module such as individual investigative project, the achievements of learning outcomes are demonstrated by project supervisors’ comments, as shown in Table 4:

Table 4: Demonstration of Achievement of Learning Outcomes: Investigative Project

Assessment of LOs
EN0360 Individual Project
Student: Elliott G (03919704) **Project title: Degradation of Chlorhexidine-digluconate by means of mixing with effluent**

LO	Criteria	Assessment 1 Draft Document	Assessment 2 Project Work & Report	Assessment 3 Viva	Threshold	Outcome
E2	To identify, classify and critically record the performance of engineering systems and components through the use of analytical methods and modelling techniques.	Partial ☑ A well-ordered approach to the background to the problem	☑ Theoretical and published work was appropriately used to underpin the investigation			
E3	To apply quantitative methods and computer software tools relevant to mechanical and related engineering disciplines, to solve complex engineering problems.		☑ A range of approaches to problem solving were demonstrated including the use of dynamic geometry within CFD software	☑ An understanding of complex modelling with commercial software was shown		
E4, D4	To apply a systems approach to engineering problems and use creativity to establish innovative solutions.	Partial ☑ The level of planning demonstrated was comprehensive	☑ Based upon solid planning a wide view of the potential solutions could be undertaken and evaluated			
D1	To investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.	Partial ☑ This project topic was derived from an environmental and H & S challenge which was satisfied	☑ A balanced view of the responsibilities of industry was demonstrated	☑ A financial and socially aware solution to an industrial problem was explained		
P4	Mastering the use of technical literature and other information sources to both obtain information and present technical data and the results and conclusions drawn from an investigation.	Partial ☑ The ability to develop an argument based upon the literature clearly shown	☑ Literature from a range of disciplines (and languages) was incorporated within a solid justification of the approach used and results presented	Partial ☑ Complex results were used to justify the project outcomes		
US3	Ability to apply and integrate advanced knowledge of other disciplines to support the investigation of a given engineering problem.		☑ Complex aspects of chemical engineering were incorporated within a well structured project and comprehensive financial evaluation undertaken	Partial ☑ A well founded understanding of commercial responsibility clearly demonstrated		
		68% (6.8)	77.83% (54.5)	75% (15.0)	40%	**76%**

It can be seen from Tables 1 - 4 that UK-SPEC’s outcome based approach has influenced significantly the articulation and assessment of learning outcomes which require a level of constructive alignment to demonstrate how the learning outcomes are specified, delivered (learning and teaching strategy) and achieved (assessment strategy and definition of threshold) so that the outputs of the degree programme are be regarded as meeting the education base competency requirements of UK-SPEC. Such requirements are also described in a similar manner in other outcome based engineering education literature (Bologna 2006, HEA 2005).

Collaboration Partner Institutions

Northumbria University's academic programmes collaborative partner institutions deliver either programmes that are "owned" by the University or programmes that are "validated" by the University. There are a number of academic collaboration partner institutions (nationally and internationally) that deliver Northumbria University's engineering degree programmes through the franchise arrangements. In addition, there are partner institutions that deliver engineering degree programs that essentially are "owned" by the respective institutions but validated by Northumbria University.

For partner institutions that deliver the University's programmes, the influence of UK-SPEC's outcome based accreditation directly affects the delivery of the degree programmes and associated modules. The UK-SPEC updated programmes and modules documentations are applicable to the respective institutions to ensure that the achievements of learning outcomes can be demonstrated. The satisfaction of accreditation criteria is essentially one that is related to ECUK and related professional bodies, for which compliance is required from the partner institutions.

For partner institutions that deliver the University's validated programmes, the influence of UK-SPEC's accreditation is propagated indirectly. Although theoretically there is no strict requirement for the partner institutions to comply with UK-SPEC, in cases where there are no conflicts between UK-SPEC and respective partner institutions obligations to satisfy a different set of accreditation requirements, it is considered to be a good practice to adopt the constructive alignment approach.

Although the influence may appear to be mainly on articulation and attainments of degree programmes' objectives and learning outcomes, the process actually functions as a dissemination function that fosters closer collaborations and forges a more unified development of global engineering education.

Conclusion

The convergence of engineering education development, as seen by the adoption of outcome based engineering degree programmes accreditation process by accreditation bodies from Europe, America and Asia, is an indication of gradual integration of engineering education.

The outcome based accreditation process of UK-SPEC has been described in some details in this paper, together with implications and influences on engineering programmes within a specific UK university and its national and international collaborative partner institutions. It can be argued that with the proliferation of global outcome based accreditation procedures a closer integration and unified development of global engineering education may be achieved.

With increased convergence, and increased level of collaborations between academic institutions, the mutual recognition of degree programmes, which is now recognised through international education agreements, may take further advantage of this closer integration. Currently, ECUK and IMechE recognise engineering education provided by many European and North America universities as being equivalent to U.K. engineering education for the purpose of accreditation (although it is the respective U.K. university's responsibility to demonstrate and maintain this equivalence) of U.K. engineering degree programmes with a one-year study abroad component, and this recognition is reciprocated by ABET. With closer international collaborations, it is hopeful that an increased level of recognition can be obtained in the future.

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