DEVELOPING OCCUPATIONAL STANDARDS IN ENGINEERING DEGREE PROGRAMMES

Melvyn Dodridge[1]

Abstract *- The generic skill requirements for engineers in the 21st Century have been relentlessly debated in the UK and in other parts of Europe and beyond in recent years. Programmes of study have been criticised because of their theoretical nature and lack of the application of engineering principles which has led to a mismatch between the skills obtained by graduates during their study in Higher Education and those requires by industry and commerce. Outcomes based assessment has assisted both educationalists and employers in measuring the skills base of a graduate but in recent years there has been a proliferation of competencies which have resulted from the findings of National bodies such as the National Council for Vocational Qualifications (NCVQ), the Engineering Council and the Occupational Standards Committee (OSC Eng). Adding value to study programmes can therefore prove attractive to both potential students and prospective employers. This paper considers the mapping of occupational standards at module level in a range of undergraduate accredited programmes offered by the Division of Electronic Systems in the School of Engineering at the University of Derby.*

THE FORMATION OF PROFESSIONAL ENGINEERS

There are three stages in the route to registration for professional engineers namely the educational base, initial professional development (IPD) and the professional review the latter being the final step before registration. After a period of IPD the competence and commitment achieved through this is demonstrated and assessed in the more stringent professional review process.

Finniston [1] talked about the 'formation' of an engineer back in 1980 which included the introduction of three levels. These were an appropriate blend of theory, application and experience and changes to the educational elements. The latter point brought about the introduction of Engineering Applications as a theme that would place more emphasis on engineering practice and less on advanced engineering theory. Engineering Applications is still an important element in curriculum design today and may be regarded as a starting point for occupational standards.

The Engineering Council's policy statement Competence and Commitment [2] published in 1995 was the successor to Standards and Routes to Registration (SARTOR) of 1990. Engineering formation was stated as a process whereby engineers and technicians could demonstrate and maintain both: -

"The competence to perform professional work to the necessary standards." and

"The commitment to maintain that competence, to work within professional codes, and to participate actively in the profession."

Competence is described in this document in terms of occupational standards. Supporting papers state that occupational standards and the National Vocational Qualifications (NVQs) that are based upon them, adhere to the definition "occupational competence is the ability to perform the activities within an occupation or the function to the standards expected in employment." These papers show the competence model specified in terms of knowledge, understanding and transferable skills where an example for a particular discipline is shown. An exemplar was needed for each occupation and a number were developed by three Industry Standing Conferences (ISC's) which were first convened 1991/92. Those produced were designed with NVQs at levels 4 and 5 in mind but as such programmes of study are normally based in the workplace very few were therefore offered by universities. There is however a limited number of such qualifications available at the higher levels today. It was recognised at the time despite the three sets of occupational standards having differences in presentation there was considerable overlap but this did not meet the impending demands for a more flexible and mobile workforce.

A completely new set of generic occupational standards were therefore produced and first published in 1998 with a revision in 1999 [3] by the newly formed Occupational Standards Council for Engineering (OSCEng).

The 3rd edition of SARTOR [4] published in 1997 describes the development of competence as "Competence is the attribute of a professional person. It is deliverable to colleagues, employers and society, and is measurable and testable."

The new SARTOR for the first time specified the requirements of professional engineers in terms of competence statements. There is some similarity between these statements and the occupational competencies specified by OSCEng.

[1] Melvyn Dodridge, University of Derby, School of Engineering, Kedleston Road, Derby, DE22 1GB
m.j.dodridge@derby.ac.uk

IPD is used to improve the acquisition and development of skills, specialist knowledge and competence needed to practice in a specific field of engineering. Whilst developing competence may be thought of as part of the IPD these standards in part can be developed as part of the educational base. The recognition of competence during the educational phase is a useful start for where it is further developed and recorded/certificated by a supervisor during IPD.

PROLIFERATION OF COMPETENCIES

Educationlists must play their part in providing a learning environment that allows skills to be developed. Skills and competence is being increasingly measured in terms of outcomes specified for example by programme generic outcomes and module outcome statements. Engineering education was considerably more focussed in terms of a narrow but deep curriculum. Today however the requirement is for a balance between depth, breadth and change. Hence the dilemma facing educators is the provision of an appropriate learning experience needed for practising engineers in the face of rapid technological change. The extensive requirements of engineering today when compared with other disciplines are depicted in models shown in [5] and [6]. Both models use a layered approach. The first layer builds foundations such as core engineering principles and technology with the other layers built on the ones below. The second layer deals with systems, not just technical ones but others such as social, organisational and business. The top layer concentrates on applications and the effects the end use has on individuals and society as a whole. These two very similar models illustrate the difficulties facing educators today. Occupational standards fit these models very well when the overall package of the educational base and IPD are considered. The curriculum today although benefiting from programmes of study with a longer duration, resulting from the raising of standards in new SARTOR, still has little room left to implement the models fully.

Outcomes and competencies are being increasingly specified in publications, many of which are policy statements. SARTOR 3rd edition and the OSC Eng occupational standards have already been mentioned but there are others. For example there are the National Key Skills Standards of the Qualifications and Curriculum Authority (QCA) and the Benchmark Standards for Engineering of the Quality Assurance Agency (QAA), the latter forming part of the mandatory 'programme specification' required in all new programmes. More recently, an output standard has been developed by the Engineering Professors Council (EPC) [7] that focuses on the generic activity of professional engineering needed to satisfy a customer's requirements, but within the constraints of the business environment. It is true that the standards are all interrelated, some more than others, but the question is raised as to whether in attempting to cover all of them is considered to be a manageable in terms of programme delivery and the student learning experience?

There is in fact good mapping between the OSCEng Occupational Standards and EPC Output Standards in those areas where there is an underpinning of academic ability and where they both focus on engineering abilities as opposed to just programme content.

OCCUPATIONAL STANDARDS

Occupational standards are standards of competence that describe what needs to be achieved in a work activity and therefore are appropriate to a practising engineer. In this context the QCA has defined competence as "The ability to perform to standards required in employment across a range of circumstances and to meet changing needs." The units of competence specified in the standards require specific knowledge and know how that is best learned experientially whilst working in the chosen occupation. National occupational standards have been primarily used in high level vocational qualifications relevant to a wide range of engineering occupations such as National Vocational Qualifications (NVQ's). They can however be used for a variety of other purposes, including traditional educational programmes of study. OSCEng defines the most important as: -

- Recruitment and personal selection
- Job design and evaluation
- Training and development programmes
- Development of education and training programmes
- Career guidance and development
- Professional requirements

Since the programmes in the Division of Electronic Systems are all accredited at Incorporated Engineer level the link between occupational standards and the competencies stipulated in the new SARTOR are therefore most relevant. Under the fourth bullet point above the following are expressed: -

- Curriculum design and development
- Relating skills based learning to workplace requirements
- Developing specific learning objectives
- Developing the knowledge content for educational training courses
- Design of qualifications

The above provide the focus for educational establishments where the main activity is educating students at undergraduate and post graduate level, both full and part-time, with the latter geared to meeting the requirements of local industry. Engineering is a vocational discipline and it is therefore not unreasonable to expect that engineering degree qualifications and their output standards should refer to and interface with nationally recognised standards such as those specified in SARTOR and OSCEng. Those engineering graduates who aspire to pursue careers as practising engineers will expect, quite reasonably, that their degree qualification will provide substantial credit towards relevant professional and vocational qualifications.

Experiential learning will build on underpinning knowledge and skills acquired through study for an engineering degree. Evidence of occupational competence in some areas can be provided by engineering degrees in which there is a match between educational and occupational standards.

The overall structure of the functional map laid down by OSCEng is shown in Table1. As can be seen the key purpose quoted is "To develop and deliver engineering products and processes," and this leads to eight units, which are further divided into 'must be able' to type statements. There is further subdivision that is not shown where the statements can be described as the assessment criteria. In order to pass the unit therefore, all of the criteria have to be met. This process can lead to a regimented reductionist 'tick box' approach similar to that used so often in QCA 'key' skills. There is therefore a danger of student over-assessment as well as an increase in the administration burden. Unlike 'key' skills a formal certificate of achievement for occupational standards is not available unless the standards are achieved through NVQ's.

The knowledge stated as required to underpin the OSCEng Occupational Standards is common to most of the units and are stated as:-

- Design principles and processes
- General and discipline-specific engineering principles and processes
- Engineering research principles and processes
- Production principles and processes
- Quality assurance principles and processes
- Data analysis methods
- Research design and methodology
- Health, safety and environmental issues
- Organisational procedures and systems
- Patents , copyright and intellectual property issues
- Specifications, details and formats
- Legislative and regulatory frameworks
- Risk analysis and assessment
- Project planning and management
- Presentation methods
- Problem solving methods
- Continuing professional development

USING OCCUPATIONAL STANDARDS IN EDUCATION PROGRAMMES

The OSCEng Occupational Standards have been mapped to four BSc (Hons) degrees. The programme titles are Electrical and Electronic Engineering, Music Technology and Audio Systems Design, Live Performance Technology and Communication Systems Technology. Whilst the former programme is regarded as traditional in terms of content the others exploit areas of technological growth. There is some shared activity between the programmes by way of 'common' modules and all students gain a thorough grasp of engineering fundamentals prior to specialisation later in the programmes.

An outcomes based assessment model has been utilised in the programmes since 1996 but the model was further refined in 1999 to take account of the requirements of new SARTOR and the looming ' programme specification' soon to become a mandatory requirement set by the QAA. The new model employed generic outcome statements for the first time as well as the traditional module level learning outcomes. The generic skills were formulated with the many requirements in mind that included occupational standards. Mapping techniques were then used to indicate the level by the way of the module(s) in which each skill was developed. Generic skills and their subsequent mapping were first discussed in these programmes in [8]. A similar mapping technique can be used for occupational standards, as it is simple to develop and understand.

Educational Excellence (EDEXCEL) is the awarding body for Business and Technician Education Council (BTEC) nationally recognised programmes of study. Their engineering programme guidelines for higher national qualifications [9] published in March 2000 was the first to illustrate by way of a map possible links between their in house devised modules and the OSCEng Occupational Standards. There has been no attempt to mould the programmes of study around occupational standards but instead to take note of naturally occurring opportunities in a similar manner to that often used for the demonstration of achievement of some transferable skills such as communication skills. The purpose as far as the division's programmes are concerned is to provide an overview of the opportunities to achieve occupational standards by way of gaining module credit through the achievement of learning outcomes. The resultant map shown in Table2 shows the standards mapped at module level and implies that the skill is developed and achieved by way of the module(s) outcomes/assessments.

A study of the map shows that many of the standards map very well with the learning outcomes developed in the modules. The standard "Improve the quality and safety of engineering products and processes" (6) may be considered

Table 1 Overall Structure of the Functional Map laid down by OSC Eng

Key Purpose	Main function	Sub-function
Key Purpose: To develop and deliver engineering products and processes	1. Develop engineering products and processes	1.1 Establish requirements for engineering products or processes.
		1.2 Initiate and specify research into engineering products or processes.
		1.3 Implement research into engineering products or processes.
		1.4 Design engineering products or processes.
	2. Produce engineering products and processes	2.1 Specify the production requirements of engineering products or processes.
		2.2 Implement the production of engineering products or processes.
		2.3 Evaluate the production of engineering products or processes.
	3.Install engineering products and processes	3.1 Specify the installation requirements of engineering products or processes.
		3.2 Implement the installation of engineering products or processes.
		3.3 Evaluate the installation of engineering products or processes.
		3.4 Commission engineering products or processes after installation.
	4. Operate engineering products and processes	4.1 Specify the operational requirements of engineering products or processes.
		4.2 Implement the operation of engineering products or processes.
		4.3 Evaluate the operation of engineering products or processes.
		4.4 Decommission engineering products or processes.
	5. Maintain engineering products and processes	5.1 Specify the maintenance requirements for engineering products or processes.
		5.2 Implement the maintenance of engineering products or processes.
		5.3 Evaluate the maintenance of engineering products or processes.
	6. Improve the quality and safety of engineering products and processes	6.1 Assess and minimise risks from engineering products or processes.
		6.2 Improve the quality of engineering products or processes.
	7. Plan, implement and manage engineering projects	7.1 Plan and specify engineering projects.
		7.2 Implement and manage engineering projects.
	8. Develop own engineering competence	8.1 Improve own ability to undertake engineering activities.

Table 2 OSC Eng Occupational Standards Module Map

Module Title	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4	5.1	5.2	5.3	6.1	6.2	7.1	7.2	8.1
Quantitative Methods	•	•	•	•	•	•				•		•		•		•		•	•	•			
Technological Skills & Practice	•			•										•	•								
Digital Electronics	•																						
Elec & Electronic Prin. & Thy	•			•								•		•									•
Communication Technology	•	•	•					•				•							•	•			•
Electrical Measurements & Testing	•							•		•	•	•			•	•	•	•					
IT & ECAD	•																						
Elec. & Electronic Services Design	•			•												•							

Year 1 Modules

Module Title	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4	5.1	5.2	5.3	6.1	6.2	7.1	7.2	8.1
CPD in Engineering		•											•	•					•	•	•		•
Microprocessor Systems	•			•										•									
Signals & Information Systems	•	•	•	•								•		•					•	•			•
Applications Programming	•			•										•									
Linear Electronics	•			•										•									
Logic Design & Applications	•			•										•									
Management & Business		•	•		•	•	•																
Project Management					•	•	•	•		•		•		•					•		•	•	•
Circuit Analysis & Design	•			•																			
Control Systems	•			•										•									
Electrical Systems Analysis	•			•										•									
Measurement Systems	•			•				•		•	•			•		•	•	•					
Work Experience	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Year 2 Modules

Module Title	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4	5.1	5.2	5.3	6.1	6.2	7.1	7.2	8.1
Digital Signals Processing Theory	•	•	•	•																			
Enterprise Management					•	•	•	•	•												•	•	•
Embedded Systems	•	•	•	•								•	•	•						•			
VHDL for Programmable Logic	•	•	•	•								•	•	•						•			
Analogue Audio System Design	•	•	•	•								•	•	•						•			
Computer Modelling	•	•	•	•			•					•	•	•						•	•	•	•
Electrical Drives	•	•	•	•	•		•	•				•	•	•					•	•	•	•	•
Electrical Power Utilisation	•	•	•	•								•	•	•						•			
Electromagnetic Compatibility	•	•	•	•		•		•				•	•	•		•			•	•	•	•	•
Industrial Control Technology	•	•	•	•								•	•	•						•			
Project (Double)	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•
Real-Time Audio DSP	•	•	•	•								•	•	•						•			

Year 3 Modules

relevant only to degrees involving manufacturing but there is scope to include this standard in many modules in terms of a general awareness. There is little mapping of the standards "Install engineering products and processes" (3) and "Maintain engineering products and processes" (5) since the programmes do not address installation and/or maintenance functions to any great extent

Modules where there is substantial project type work are a good vehicles to develop many of the standards as the map clearly shows. "Manage engineering projects" (7.2) is mapped to the Project module but there may be considerable difference in the emphasis when considering part-time students who are engaged in industrial projects as opposed to full-time students who are mainly involved in 'in house' projects. Nether the less the latter students are subjected to many of the constraints they would meet in industry.

The module Work Experience is mapped against all the standards but like the Project module the actual selection will vary considerably. This is a new module to be offered this coming academic year and will provide a placement period of about six weeks. The traditional 'year out' offered in sandwich provision has not been successful because it has proven difficult to place students, as most of the 'high tech' companies are small to medium enterprises (SME's). It is anticipated that this situation will improve due to the shorter period and with the help of organisations who can arrange placements. Research has shown that students with work experience have a better chance of finding a job after graduation and according to one placement organisation this is more than double.

CONCLUSIONS

The implementation of this project is the next stage. As already stated there is no intention to change the nature of the programmes to incorporate OSCEng Occupational Standards where the emphasis is on occupationally specific knowledge and its application in the workplace to particular tasks. The programmes offered will continue to develop general engineering principles and view applications of these principles as industry non-specific. Transferable or 'key' skills are increasingly sought by employers and are not included as part of the OSCEng standards but in many cases well developed 'key' skills are implied by the engineering activity required. There is however the necessity to assess 'key' skills as they form one of the four areas specified in the QAA 'programme specification.' The intention however is to ensure that graduates from the programmes will be well prepared for a career in most engineering occupations and that they will have gained credit towards relevant professional and vocational qualifications.

The next step in the process of implementation poses a challenge since it will be necessary to look carefully at module learning material including assessments to ensure that the outcomes are achievable. This process will not happen overnight but will evolve and be monitored by peer group appraisal. It is important to try to look for naturally occurring opportunities as this will avoid over-assessment.

In conclusion the added value brought about by the introduction of occupational standards should bring benefits to both students and employers. The 'mis match' between what we as educationalists produce as opposed to what industry expects can therefore be addressed.

REFERENCES

[1] Finniston, F.: *Report of the Committee of Enquiry into the Engineering Profession,* Cmnd, 7794, HMSO, 1980.

[2] *Competence and Commitment*, The Engineering Council, London, 1995.

[3] OSCEng – *Engineering Occupational Standards for higher levels*, Occupational Standards Council for Engineering, Parameter Research, 1998 and 1999

[4] SARTOR – *Standards and Routes to Registration, 3rd edition*, The Engineering Council, London, 1997.

[5] Lee, E. A., Messerschmitt, D. G.: A highest education in the year 2049, *Proc.* IEEE, Sept. 1999, Vol. 87, No. 9, pp.1685-1691.

[6] Midwinter, J. E.: Something old, something new and something just in time: dilemmas for EE education and training, *IEE Eng. Sci. & Ed. J.,* Oct.2000, Vol. 9, No. 5, pp. 219-230.

[7] The EPC Engineering graduate output standard- interim report of the EPC output standards project, *EPC occasional paper no. 10,* Dec. 2000

[8] Dodridge, M. J.: Generic skill requirements for engineers in the 21st Century, *Frontiers in Education conference*, Nov. 1999, San Jose, Puerto Rico

[9] BTEC Higher Nationals in Electrical/Electronic Engineering: guidance and units (2000)-Annex D, *Edexcel Foundation*, Mar. 2000
www.edexcel.org.uk