Introduction to reports of the Working Groups
Tim Whiteley
11/03/02

1997 was an eventful year for UK Engineering higher education. Not only did it see the publication of the report of the National Committee for Enquiry into Higher Education (the Dearing Report) (HMSO,1997) and the establishment of the Quality Assurance Agency (QAA) but also the publication of the Engineering Council's Policy Document 'Standards and Routes to Registration - 3rd Edition' (Engineering Council 1997), more commonly known as SARTOR 3 . The latter set out the Engineering Council's intentions regarding the criteria for future accreditation of engineering degree courses as providing the appropriate educational base for registration as an engineer.

A feature of the criteria was the use of minimum engineering-course input standards defined in terms of A-level points scores. The EPC was convinced that the best graduates from UK Engineering Degree courses were, by any measure, as good as ever and compared favourably with the graduate engineers of international competitors. However, it shared some of the Engineering Council's concern regarding an increasingly 'long tail' of those graduating from engineering courses, usually with lower degree classification, who proved to have relatively modest achievement and capability.

Concurrently, EPC had been aware of a growing and increasingly-articulated perception amongst some employers that the HE system was not producing enough engineering graduates with the skills and attributes they required. On the other hand, members of EPC Committee, through their work as examiners, accreditors and quality-auditors, believed that there continues to be many excellent engineering courses producing good graduates who compare favourably with graduates from other disciplines and with those of engineering courses in other countries.

Although many of the negative comments imputed to some industry and government bodies were not supported by evidence to show that this view was widespread and valid, EPC recognised that perceptions are frequently as important as the reality. It seemed likely that a contributory factor in the apparent contradiction was a mismatch between the expectations of graduate capability of employers on the one hand and HE on the other. In the absence of agreed engineering graduate output standards, this mismatch seemed unlikely to be resolved.

To address the related issues of Engineering Council educational requirements and the apparent mismatch of expectations, EPC decided to undertake a project to establish standards for engineering graduates at the output of their engineering degree course - the EPC Output Standard Project, which started in 1998.

Following widespread consultation both within higher education and with other key stakeholders such as employer organisations and accrediting bodies a standard was produced, defining the expectation of the attributes of all engineering graduates in terms of 26 generic statements of graduates' 'Ability to.'. These statements formed the essential framework of the EPC Standard describing what all graduates must be able to do but were insufficient on their own to describe the level of the expected ability. It was intended that the level of activity within the framework of 'Ability to' should be exemplified by illustrative statements from providers of engineering degree courses which would then, following normal processes of peer review, come to provide an agreed picture of a reasonable expectation of the abilities of all engineering graduates. Such statements were (and are) referred to as exemplar benchmarks.

The standard and methodology were tested by nine 'pilot' universities who developed benchmark statements for a range of their engineering programmes in the main engineering disciplines.

Following the successful piloting of the standard, five working groups were set up to undertake specific additional tasks, reporting to an overarching co-ordinating group:

- **Incorporated Engineer Working Group (IEngWG)** - taske
  the EPC Output Standard is applicable to and can be bench

programmes for IEng aspirants;

- **Professional Bodies Working Group (PBWG)** - tasked with exploring the accrediting bodies of an output standard applicable across all engineering
- **Employers' Working Group(EWG)** - tasked with clarifying the benefits to of the EPC Engineering Output Standard and with identifying significant on modifications necessary to better reflect the needs of employers;
- **Compatibility Working Group (CWG)** - a joint working group with QAA, ta demonstrating the compatibility of the EPC Output Standard with the QAA statement for engineering graduates;
- **Assessment Working Group (AWG)** - tasked with supporting engineering departments in the development of effective and efficient assessment proc appropriate to the implementation of EPC Engineering Output Standard.

Reports from all groups have recently been published and distributed through the EPC Representative Members network. They are also available on the EPC website at [www.engprofc.ac.uk]. The reports are substantial and provide a rich mine of information and insights but the key findings are:

- The EPC Standard provides a language and a framework w and comparison of expected engineering graduate abilities a disciplines by all interested stakeholders.
- The framework of 'Ability to...Statements' provided by the E Output Standard is equally applicable to benchmarking for I the Standard can be used to define the expected abilities, a level, of graduates from programmes intended for both CEn
- Professional Engineering Bodies should be encouraged to r concentration on the assessment of input to a more explicit criteria where appropriate and possible. Although the existir robust, the assessment of graduate output could be improve standard such as the EPC Output Standard. This improvem through harmonisation of the EPC, QAA and EC approache as to allow accreditation committees to make sound judgme
- The EPC Standard appropriately defines the abilities expect engineering graduates. Nevertheless, employers have found 'Ability to..' statements into an alternative formulation using accessible, albeit less precise and inclusive, to an employer of potential benefit to employers as a means of providing re information on the individual abilities of engineering graduat

classification of the degree awarded.

- Key Skills, defined by the Qualifications and Curriculum Authority as those Communication, Information Technology, Application of Number, Working Others, Problem Solving, Improving own Learning and Performance are an component of the EPC Standard but are not explicitly benchmarked in it. E emphasise that, in interpreting and using the standard, the Key Skill requ must be given the full value implied by their inclusion as the very first of the to..' statements and that team-working should be given special emphasis.
- There is no significant incompatibility between the QAA Subject benchmar for Engineering and the EPC Output Standard; although the statements in publications were developed from different perspectives, they say very sim in different formats. Both can provide course designers with reference poin continuing innovative development of academic programmes.
- Existing assessment techniques are capable of being used to assess the c authentic achievements defined by the 'Ability to..' statements of the EPC but the reliability of each technique varies according to context. This uncer reliability should be made clear to all stakeholders (students, academics ar employers).
- There are assessment methods in use in other disciplines which may well engineering and be particularly effective in assessing the output standard. example, student portfolios can form the basis of direct dialogue between s and prospective employers.
- Programme-level (rather than module-level) design should drive the introd overarching
- Programme-assessment strategy consistent with externally-generated outp standards. A systemic approach using best assessment scholarship has p reduce long-term operational assessment costs.

The work of the Assessment Working Group is incomplete. It intends to collaborate with LTSN Engineering Subject Centre on assessment issues and to work with engineering departments to produce tools and examples to help in assessment development. An Assessment Workshop planned for Summer 2002 will initiate this.

Your views on the contents of the reports referred to above is urgently solicited, so as better to shape the direction of future work to the benefit of EPC members.

Please send your comments to:

Mrs Fiona Martland Executive Secretary
Engineering Professors' Council
c/o The Institution of Mechanical Engineers,
1 Birdcage Walk
Westminster
London
SW1H 9JJ

By the end of May. A summary of responses will be added to our web site.

Report of the Assessment Working Group

The EPC Engineering Graduate Output Standard

Assessment of complex outcomes

January 2002

The Engineering Professors Council

Published by
The Engineering Professors Council
Secretariat: c/o Institution of Mechanical Engineers
1 Birdcage Walk
London SW1H 9JJ
England

Printed in England by
Training Publications Ltd
Watford

Acknowledgement
Thanks are due to Tim Feest, Director of OSCEng, for help with editing and formatting of the report for printing.

Contents

Summary

1 In response to concerns about the competencies of graduates of UK engineering degree programmes, the EPC generated an output standard which provides a language with which attainments of graduates of engineering degree programmes can be described. These attainments are couched in terms of 26 benchmark statements of graduate 'Ability to'. Different disciplines (civil, mechanical, electrical etc), and different degree types (BEng, MEng) lead to specific sets of benchmark statements for each combination, expressed in the language of the output standard. This output standard is a first stage: the second stage is to be able to find some way of demonstrating that graduates have indeed attained the levels implied by these benchmark statements: some way of assessing the output standard is required. The present report has been prepared by the Assessment Working Group (AWG) of the EPC as a first step to achieving this next stage of implementation of the output standard.

2 There are many different techniques that are used in assessing students in the course of undergraduate degree programmes in engineering – and several different purposes for which assessment is conducted. One of the important aims of this report is to emphasise that different assessment procedures are most appropriate for different purposes and that the assessment procedures should be chosen for their particular application. Assessment for formative purposes – to help students in their learning – is not usually well suited for summative purposes such as providing an indication of degree classification or helping universities to decide whether students should be allowed to proceed to a higher level within a degree programme.

3 There are many different techniques that are used in assessing students in the course of undergraduate degree programmes in engineering – and several different purposes for which assessment is conducted. One of the important aims of this report is to emphasise that different assessment procedures are most appropriate for different purposes and that the assessment procedures should be chosen for their particular application. Assessment for formative purposes – to help students in their learning – is not usually well suited for summative purposes such as providing an indication of degree classification or helping universities to decide whether students should be allowed to proceed to a higher level within a degree programme.

4 There seems to be no requirement to generate novel forms of assessment in order to be able to assess all the 'Ability to…Statements' within the EPC output standard. However, the reliability associated with each technique varies. This uncertain reliability should be made clear to all stakeholders (students, academics and employers). Nevertheless, there are assessment methods in use in other disciplines which may well translate to engineering and be particularly effective in assessing the output standard. For example, student portfolios can form the basis of direct dialogue between students and prospective employers. Logically, overall assessment strategies should be devised in association with overall degree programme design which itself should be conducted in the light of output standards generated externally to the educational institution.

5 Changing existing practices is expensive in staff time and energy. There are costs arising from the implementation of enhanced assessment systems, as well as from the output standard itself. As far as the assessment costs go, the Assessment Working Group believes that a systemic approach using best assessment scholarship has some potential to reduce long-term operational assessment costs. However, it is recognised that there is a degree of scepticism about the EPC output standard itself and sceptical staff will require

much convincing before they are prepared to invest resources in changing current practices in the quest for a *possibly* improved future.

6 The AWG recognises that there is a major challenge ahead in getting UK engineering departments to adopt any of the suggestions for systematic review and modification of assessment practices.

7 The EPC is not alone in recognising the difficulties associated with assessment, particularly in the context of the adoption of an output standard. A good working relationship has been developed with the UK Learning and Teaching Support Network's subject centre for engineering which augurs well for the medium-term support for the implementation of new assessment systems. A jointly-organised workshop on assessment will take place in the summer of 2002: this is intended both to develop a common understanding of the language of assessment within the academic engineering community and to generate examples of good practice which can be disseminated to all interested universities. In parallel with the present report the LTSN Generic Centre has produced a comprehensive series of guides to many issues associated with assessment in higher education. These constitute an extremely valuable resource for hard-pressed academics.

8 In short, empirical work with EPC members suggests that while the output standard raises a number of practical problems, it is possible to envisage fair and worthwhile assessments of its twenty-six 'Ability to…Statements', assuming that best thinking about assessment is deployed. It should be appreciated that engineering departments will need sensitive help if they are to engage successfully with what will often be substantial changes to infuse their programmes with best assessment practice.

1 Introduction

To address the related issues of Engineering Council educational requirements and the apparent mismatch of expectations between employers and HE providers, EPC has undertaken a project to establish standards for engineering graduates at the output of their engineering degree course: the EPC Output Standard Project. Following widespread consultation both within Higher Education and with other key stakeholders such as employer organisations and accrediting bodies a standard was produced, defining the expectation of the attributes of all engineering graduates in terms of 26 generic statements of graduates' 'Ability to'. These statements formed the essential framework of the EPC Standard describing what all engineering graduates must be able to do.

It was always recognised that the generation of a series of subject benchmark statements to go alongside the generic 'Ability to…Statements' could not really be separated from consideration of issues of assessment. If it is *claimed* that graduates have certain abilities then it must presumably be possible to demonstrate that they do indeed have these abilities. The report of the Output Standards Project was thus an interim report and subsequently an Assessment Working Group (AWG) was formed to support engineering departments in the development of effective and efficient assessment processes appropriate to the implementation of EPC Engineering Output Standard by:

- reviewing current assessment methods and identifying good practice as it relates to engineering;
- evaluating, in terms of validity, reliability, utility and efficiency, current assessment methods in relation to their use with the EPC Engineering Output Standard;
- formulating guidance on assessment strategies and practices for use with the EPC Engineering Output Standard.

In discussing assessment it is necessary to consider both the various different reasons for endeavouring to assess students and the various groups (stakeholders) for whom information on assessment is of interest or concern. Universities typically assess under four headings:

1. Formative Assessment – for the benefit of the student, to provide rapid feedback on learning;

2. Progression – to guide the university in decisions whether a particular student is ready to proceed to the next year of a degree programme;

3. Classification – to enable the university to award labelled degrees (first class, upper second class, etc);

4. Warranty – to enable employers to be confident of the skills of the graduating students that they may seek to employ.

The EPC output standard is primarily concerned with the last of these but it is clear that assessment for warranty is unlikely to be sufficient on its own. Equally, however, while each of these four demands for assessment may have their educational desirability it cannot be expected that a mode of assessment that is ideal for one purpose and one constituency will be equally helpful for another.

Warranty has not explicitly been a part of the assessment output from universities. Employers (and organisers of higher degree programmes) have typically taken classification as a surrogate and have trusted universities to award degrees as an indicator of satisfactory completion of a valid educational experience. Even among employers the elements of the warranty that are of interest will differ: some will look for immediate application of technical knowledge (such as an ability to design the reinforcement in the connection between a concrete beam and column) whereas others may be looking for other, less easily measurable, qualities (such as an ability to devise and analyse novel structural forms over the coming decade). Universities may not be able to guarantee that their graduates have the latter skills though they may be able to provide opportunities for open-ended work which allow students to demonstrate an original flair.

Universities use a range of different techniques for assessing students – these will be discussed in subsequent sections. There is naturally a substantial reliance on traditional unseen examinations in which candidates are required to answer 4 out of 6 questions (say) and are required to obtain a pass mark of 40%. Often papers are grouped so that good performance in one paper can compensate for poor performance in another. With this sort of evidence it is not even possible to guarantee that graduates will have demonstrated competence in any particular technical subject.

The concept of a 'threshold' is relatively new to higher education although familiar in other sectors of the education world. In higher education, 'compensation' has traditionally been used to enable a weakness in one area to be compensated by a strength in another area. However, for a threshold to indicate a reliable minimum expectation of a particular competence, compensation is an inappropriate approach. Recognising this, and devising rigorous yet sensible ways to deal with an untypical weakness in the overall profile of a student, could well be one of the most significant challenges of this whole project.

There is a general perception among students that they are over-assessed and among staff that they are over-assessing. It is an unfortunate truism that students, especially at the start of their university studies, are unlikely to take seriously anything that is not assessed in some way. Good assessment arrangements, providing 'sticks and carrots' over the duration of the degree programme, can help all teachers, and not just the most inspirational, to motivate the majority of students. Staff are also aware that the area where there is most likely to be a direct tangible reward for effort comes from research. The motivation for devoting time and energy to a *perceived* upheaval which may (or may not) result in a reduced burden of assessment is thus probably low. The obstacles to producing major changes in the way in which assessment is conducted and to the introduction of new assessment practices in association with the EPC or any other output standard are clearly very real.

Undaunted, the present report tries to provide an overview and critique of some of the techniques that are presently used for assessment in university engineering education and endeavours to present a strategy for helping universities to reform their programmes of assessment. In summary, the report is presented thus:

Section 2:	describes the context within which the EPC output standard has been produced and relates it to other parallel relevant activities;
Section 3:	discusses assessment in relation to the output standard;
Section 4:	reviews current assessment practices in engineering;
Section 5:	begins to develop practical assessment methodologies;
Section 6:	suggests the way ahead – specifically proposing an extended workshop on engineering assessment during 2002 which is intended to emerge with some 'worked examples' of assessment possibilities which can be offered to the academic engineering community.

The work on assessment which is the subject of this report constitutes part of a comprehensive study aimed at exploring the benefits to Higher Education and other key stakeholders, such as employers and professional bodies, of using the EPC Engineering Graduate Output Standard. It is being prosecuted by five working groups, of which the Assessment Working Group is one.

The others are :

- Professional Bodies' Working Group (PBWG)
- Employers' Working Group (EWG)
- Incorporated Engineers' Working Group (IEngWG)
- Compatibility Working Group (EWG)

The work benefits from advice and funding from an Output Standard Advisory Group, with representatives from a wide constituency of interested parties, and the tasks and of each working group are co-ordinated by an Output Standard Co-ordinating Group (OSCG).

The EPC Standard itself, its rationale and development, and exemplar benchmarks from the pilot universities are described fully in 'The EPC Engineering Graduate Output Standard – the Interim Report of the EPC Output Standards Project' [EPC, 2000].

2 Context

2.1 EPC Output Standard

1997 was an eventful year for UK Engineering Higher Education. It saw the publication of not only the report of the National Committee for Enquiry into Higher Education (the Dearing Report) [HMSO,1997] and the establishment of the Quality Assurance Agency (QAA) but also the Engineering Council's Policy Document 'Standards and Routes to Registration – 3rd Edition'[Engineering Council 1997], more commonly known as SARTOR 3. The latter set out the Engineering Council's intentions regarding the criteria for future accreditation of engineering degree courses as providing the appropriate educational base for registration as a professional engineer.

A key feature of the SARTOR criteria was the use of minimum engineering-course input standards defined in terms of A-level points scores. While the Engineering Professors' Council (EPC) was convinced that the best graduates from UK Engineering Degree courses compared favourably with the graduate engineers of our international competitors, it shared some of the Engineering Council's concern regarding an increasingly 'long-tail' of those graduating from engineering courses, usually with lower degree classification, who proved to have relatively modest achievement and capability. The routine use of A-level scores at input to a degree course is not seen as a reliable indicator of engineering ability and potential at output.

At the same time, EPC was aware of a perception amongst some employers that the HE system was not producing engineering graduates with the skills and attributes that they thought that they required. On the other hand, members of EPC Committee, through their work as examiners, accreditors and quality-auditors, believed that many engineering degree courses were producing graduates who could be compared very favourably with graduates from other disciplines and with engineering courses in other countries.

Although many of the negative comments attributed to some industry and government bodies were not supported by evidence, EPC recognised that perceptions are frequently as important as reality. While a contributory factor in the apparent contradiction might be a mismatch between employers' expectations of graduate capability on the one hand and HE views of the purpose of engineering education on the other, in the absence of any agreed engineering graduate output standards, resolution of this mismatch seemed problematical. EPC therefore decided in 1998 to undertake a project to establish standards for engineering graduates at the output of their engineering degree course – the EPC Output Standard Project.

Following widespread consultation both within Higher Education and with other key stakeholders such as employer organisations and accrediting bodies a standard was produced, defining the expectation of the attributes of all engineering graduates in terms of 26 generic statements of graduates' 'Ability to'. These statements formed the essential framework of the EPC Standard describing what all graduates must be able to do. They were, however, insufficient on their own to describe the level of the expected ability. It was intended that the level of activity within the framework of each 'Ability to…Statement' should be exemplified by illustrative statements from providers of engineering degree courses in particular disciplines which would then, following normal processes of peer review, come to provide an agreed picture of a reasonable expectation of the abilities of *all* engineering graduates. Such statements are referred to as exemplar *benchmarks*.

The standard and methodology was validated by nine 'pilot' universities who developed benchmark statements for a range of their engineering programmes in the main engineering disciplines. All but one of the sets of benchmark statements were intended to illustrate the threshold level of BEng programmes intended primarily for those aspiring eventually to Chartered Engineer status but, for one programme, examples of benchmark statements describing a threshold at MEng level were provided. This illustrates one of the fundamental strengths of the EPC Output Standard: the generic 'Ability to…Statements' provide a framework describing what *all* engineering graduates must be able to do, which individual programmes can then benchmark to describe and communicate the intended threshold level. In fact, realistically, it may be that this *framework* is the most valuable result of the Output Standard project, providing a common language which different stakeholders can use to describe their desires or attainments, at whatever level may be of concern.

Thus it was proposed that the same approach might also be used to establish a threshold level for programmes designed to meet the needs of those aspiring to Incorporated Engineer status (IEng degrees): a view strongly supported by employer organisations and Incorporated Engineer professional bodies. An IEng Working Group set up to generate exemplar benchmarks for IEng degrees has tested the validity and applicability of the EPC Output Standard for this kind of degree: its findings are the subject of a separate report.

2.2 The role of QAA and of Professional Engineering Bodies

The Assessment Working Group recognises that its activities, if they are to be credible and acceptable to the engineering community, must take cognisance of the broader education context. Key drivers of this context are the QAA, the Professional Engineering bodies, the government in terms of its influence over Higher Education and its drives for widening and increasing participation, and the European dimension. Some of this broader context is summarised here.

The QAA is the current body established by the government to address the breadth of quality within the Higher Education system. Its stated mission is "…to promote public confidence that quality of provision and standards of awards in higher education are being safeguarded and enhanced." Included amongst its outputs that have an immediate bearing on the activities of the AWG are the subject and academic review processes, subject benchmarks, the National Qualifications Framework and the Code of Practice on Assessment.

2.2.1 Benchmarks and output standards

The QAA has produced for the engineering profession as a whole, an 'Academic Standards – Engineering' document that details 'generic statements which represent general expectations about standards for the award of honours degrees in Engineering.' While this document could represent an 'alternative' to the EPC output standard, since it is seen as having government backing, it will be perceived as the controlling standard no matter what public pronouncements are made to the contrary. In fact, of course, this standard is one of a number of such statements that are in the academic domain. Other reference points for programme designers include those offered by the accrediting Professional Bodies such as the IEE, the BCS, etc. At present there is currently an absence of a clear, unifying definition of the output standards that all stakeholders accept and are adopting.

2.2.2 Quality review

The first stage of the subject review process is now complete. The second, as currently proposed, may take the form of a 'lighter touch' institutional review. The key objectives of the quality review process are the introduction and maintenance of quality standards and the establishment of processes within each academic institution for ongoing quality management and enhancement. An integral part of the review process is the formulation of documented descriptions of programmes offered and procedures used to assure quality. Alignment of degree programmes with output standards – whether those of EPC, QAA or accrediting bodies – could result in the need to change procedures and descriptions and hence impact on the quality documentation.

2.2.3 Module and Programme Specifications

The QAA quality review process has defined the need for programme and module specifications. These specifications introduce the need, on the part of the programme designer, to consider assessment issues from the outset. The AWG output should have a direct impact on the assessment aspects of these documents.

2.2.4 Progress files

The AWG has identified progress files as a valid assessment instrument and notes they are likely to fit well as part of the overall assessment strategy for an academic programme. They may be particularly useful when it comes to assessing 'Ability to…Statements' which are not well-suited to highly-reliable assessment methods.

2.2.5 National Qualifications Framework (NQF)

The NQF defines five levels of higher education qualifications that can be awarded by universities and colleges. The NQF descriptors "exemplify the outcomes of the main qualifications at each level". The two key levels for the AWG activities are the Honours (H-level) and Masters (M-level). It is noted that "Some Masters level degrees in science and engineering are awarded after extended undergraduate programmes that last, typically, a year longer than Honours degree programmes." This clearly indicates that the MEng should be a Masters level award; and this is currently at odds with many institutions that award classifications to MEng degrees, typically the province of undergraduate degrees, instead of the Pass/Fail/Distinction awards of the typical masters level award. The Engineering Council and the Professional Bodies are, at the time of writing, adopting an advisory stance in this matter. The QAA is clear in its support for the NQF stance.

2.2.6 Levels and articulation of progression requirements

The AWG has based its current thinking on the EPC output standards, as an articulation of the achievement threshold for a Bachelors degree. Some work has been carried out to demonstrate that a set of thresholds can also be formulated, using the vocabulary of the same output standard, for the MEng threshold. Such work could help to inform the definition of the achievement expectations at the end of the second year where MEng progression is decided.

2.2.7 Treatment of failed marks and compensation

The AWG has noted the current widespread variation across academic institutions on ways in which failed marks are condoned and what constitutes acceptable compensation. Some institutions group units together and require satisfactory performance in the group but not necessarily in individual units. Others have formulaic schemes for allowing good overall performance to compensate for specific weaknesses. Both of these create problems for the application of an output standard which attempts to guarantee competency of individual graduates in particular technical areas.

2.2.8 Engineering Council and SARTOR

As has already been mentioned, the Engineering Council and the Professional Bodies are currently taking an advisory stance on issues such as the naming of awards and their categories, how fails and compensation should be addressed at the detail level and on the details of assessment. The current practice is to leave institutions to propose their own practices and leave approval to the accreditation process. Current experience of response to enquiries suggests that guidance is only given at the general level. The EPC Professional Bodies' Working Group is looking specifically at the use that the accrediting professional bodies might make of the EPC Output Standard.

2.2.9 Widening participation

The output standards and quality debate should be considered against the backdrop of the government's present drives for widening and increasing participation. The Government's aim is that by 2010 50% of young people should have the opportunity of benefiting from higher education by the time they are 30. An associated issue is then the quality and source of the 'raw material' for engineering degree programmes. The traditional source is the A-level system which, over the past decade, has seen a number of structural changes. Hard evidence now indicates that the real quality of a grade A at A-level mathematics is not what it used to be. Evidently, locking the output of the higher education system in the presence of falling input standard results in a need to increase the student added educational value and more tension within the higher education system.

2.2.10 The European dimension

The UK, as a member of the European Union, has signed up to the Bologna Agreement. This agreement is to establish a 'European system of higher education' by 2010. This system is based on two main higher education cycles, undergraduate (first-cycle) and postgraduate (second-cycle). The duration of first cycle degrees is 3 to 4 years and the duration of the second cycle degree is 1 to 2 years with an implied overall time to achieve a second cycle degree of 5 years. So far as engineering is concerned this might be interpreted as a first cycle degree devoted to the *process* of engineering followed by a second cycle degree devoted to engineering in a particular *context*.

The current UK higher education system of a 3-year undergraduate bachelors degree followed by a 1-year undergraduate masters degree is partially at odds with this model. Of perhaps more significance is any impact the Bologna Agreement might have on the current debate over whether the MEng is a true undergraduate or postgraduate qualification.

2.2.11 Learning and Teaching Support Network (LTSN)

The LTSN Generic Centre (LTSNgc) has produced a series of twelve reports on general assessment issues (Generic Centre, 2001). While these are not specifically related to assessment of engineering degree programmes, several relate to proposals that are made and issues that are identified in this report: for example, report 6 is concerned with assessment of portfolios; report 9 with self, peer and group assessment; report 10 with plagiarism; report 12 with assessment of large groups. LTSN obviously provides a route by which output of the Assessment Working Group can be disseminated to the academic engineering community. One of the next steps that is being proposed (section 6) is to work with the LTSN Engineering Subject Centre (LTSNeng) to develop feasible strategies for assessment which are capable of implementation in support of output standards.

3 Assessment of student learning in relation to the output standard

This section summarises some fundamental ideas about human achievements, assessment and measurement and relates them to the justifiably-complex ambitions of the EPC Output Standard. It shows that the AWG's recommendations mesh with policy developments, student learning needs and advanced research thinking.

3.1 The assessment of student learning – some distinctions

Most assessment in higher education is summative. It warrants or certifies students' achievements. There is a well-established distinction between assessment that has summative purposes, which means that it is a high-stakes, graded judgement of achievement, and that which has formative purposes. The aim of formative assessment is to provide an opportunity for students to experiment in a 'safe' environment and to identify their own level of performance and how they might improve their future performances. With formative assessments the stakes are perceived to be lower; less is visibly at risk if there is error in the judgement.
Any learning achievement can be the subject of low-stakes, formative assessment, even complex ones relating to ill-defined or 'soft' skills. In such circumstances it would be hard to claim that the assessor's judgement would be as reliable[1] as, say, a score on a set of multiple choice questions (MCQs), but that need not matter. The purpose is conversational, the anticipated outcome is learning and learning often involves dialogue. Seen like that, the assessor's judgement is a starting point in a learning conversation. It is not a final judgement and, although it should obviously be a fair judgement, it does not have to be reliable in the same way as summative assessments.

When the purposes of assessment are summative and to provide 'feedout', reliability is at a premium. Some achievements can easily be reliably assessed. These assessments are called 'low-inference' assessments and are typified by MCQ tests of information retention. Low-inference assessments may be reliable but they only work with determinate achievements where there is little ambiguity about the correct answer. EPC output standards put considerable emphasis on achievements that are far more complex, where credit could be given for a range of solutions and for the means by which the solutions were developed. Although there is a temptation to use low-inference measures, such as MCQ tests of information retained, as proxies for such complex achievements, their reliability is bought by reducing complexity to simple proxy measures. In other words, there are sharp questions to be asked about their validity[2] or worth. Where complex learning achievements are in question, there is a tension between the demands of reliable assessment and the requirements of valid assessment. In a paper prepared for the AWG, Hamer and Macintosh (2000:3) said that accuracy, which can be taken to be a facet of reliability, is not enough. They added that: 'Assessment practices that have as their main goal the chimera of precision will fail to meet both the needs of the individuals at whom they are directed and of the society of which they are a part.'

3.2 Can all 'Ability to…Statements' be assessed?

It will be apparent by the end of this report that all the 'Ability to…Statements' *can* be assessed in some way. However, that does not mean that all can be summatively (reliably) assessed, let

[1] Reliability is taken here to mean that if a judgement were made by some other process, some other person or even if the evidence of performance were re-judged by the original assessor, then all of these routes would lead to the same judgement.
[2] A valid assessment assesses what it intends to assess, and not some other performance. For example, a written (lab) report is not the most valid method of assessing a practical skill.

alone within the resources available to most departments. Unfortunately, high validity and high reliability only go together when simple, determinate achievements are being assessed. In fact reliability itself is costly, can be difficult to achieve, and is often to be bought by using artificial techniques that may be poor predictors of life-like performances. Complex processes are required to judge complex abilities and the more complex the abilities which the performance is supposed to show, the more samples are needed and the more complex is the assessment process.

The process can be simplified but only by simplifying that which is to be assessed so that simplification is at the price of validity. For example, the ability to transform existing (complex and fuzzy) systems into conceptual models, which are then to be transformed into determinable models is a sophisticated set of problem-*working* abilities. It is not validly assessed by tasks in which parameters are set for the student so that standard methods can be routinely applied to *solve* the problem. This may make for more reliable assessment but in the process the abilities in question have become simplified: routine problem-solving has been substituted for complex problem-working. If validity is to be preserved, reliability costs soar.

The EPC has set an output standard that authentically reflects engineers' work processes. Inevitably, some parts resist reliable assessment and others are only open to tolerably reliable assessment if resources are invested in well-trained graders using good-grade indicators to judge many pieces of work providing evidence of 'Ability to' achievements. Exactly which learning outcomes can be warranted depends partly on:

- The nature of the outcome (there is no great problem with the reliable and cheap assessment of information retention);
- How assessors decide to treat the outcome (any complex achievement can be simplified to make it easier to assess: it is a professional decision whether that loss of validity matters);
- How much cunning, time and money are invested in measures to increase reliability (authentic assessments of complex performances tend to be unreliable but acceptable reliability levels can be achieved at a price).

It follows that the EPC may wish to advise the engineering community about:

- The outcomes that are best suited to summative assessment and best practice in summative assessment;
- The outcomes that are well-suited to formative assessment and best practice in formative assessment;
- How students might learn to make claims to achievement in relation to output standards that are not summatively assessed. Portfolios may be an answer.

3.3 Improving the reliability of summative assessments of complex achievements

Four suggestions for improving the reliability of summative, high-stakes assessment are made here.

3.3.1 Standards development

Chapter 2 of the *Interim Report* fleshes out the 'Ability to…Statements'. Further elaboration would serve three purposes:

- Elaboration helps colleagues to understand the operational meaning of standards;

- The process of elaboration gives advance warning of points that are likely to prove problematic;
- This process is also a great spur to learning for those involved.

The AWG might explore ways in which elaboration and exemplars can be provided on paper, electronically (including on-line discussion groups), through discussion groups and conferences. The QAA expectation that programme specifications will be written for all awards could provide a ready-made opportunity for colleagues to develop understanding of the standards by trying to embed them in programme specifications *and* to be able to talk with others in a national engineering network as they do so. The AWG's summer (2002) workshop is designed to capitalise on these possibilities (see Section 6).

3.3.2 Curriculum design to provide repeated opportunities for assessing these achievements

In some subject areas and in some universities the idea of a programme-wide assessment strategy is unknown. The output standard is a *programme* standard with the implication that programme assessment strategies are needed. An assessment audit is a good starting point, allowing departments to ensure that, across a complete programme, there are repeated occasions for the assessment of benchmark attainments by means of authentic tasks using a range of assessment methods and calling upon the expertise of multiple assessors.

A key idea in the measurement of human achievements is that repeated assessment is a prime requirement for reliable conclusions. In applying this to the 'Ability to…Statements' we are saying quite clearly that *across a programme* there must be repeated judgements made of each 'Ability to…Statement' that a department wants to certify or warrant with a tolerable degree of reliability. Not all of the 26 'Ability to…Statements' will be certified in this way because some are scarcely compatible with affordable and reliable assessment. As for the rest, reliable conclusions depend upon repeated judgements using consistent grade indicators. Departments will decide for themselves how many judgements each 'Ability to…Statement' needs. In some cases they will find that audits tell them that some abilities are over-assessed and need *less* attention. As for other 'Ability to…Statements', they will find that *more* assessments need to be distributed across the programme in order to guarantee reliability.

At module level the effect on the volume of assessment should be neutral, although teachers may find themselves encouraged to direct their judgements to new statements and away from others.

3.3.3 Standards familiarisation

Reliable assessments require that assessors and learners share a common understanding of the criteria and standards being applied. There will be a pressing need within engineering departments for training in understanding and applying outcome standards to new, complex assessment tasks. However, unless there is a sustained programme of action to try and secure a range of shared meanings and practices amongst the UK's engineering departments, the new outcome standards may be interpreted and applied at departmental level in quite different ways. Standards familiarisation should be recognised as a necessary implementation cost.

3.3.4 Criteria, threshold standards and grade indicators

The output standard is described under seven main headings. These headings are further sub-divided for clarity and completeness. For example, 'Ability to…Statement' Two has seven sub-statements. These may be seen as seven criteria, which describe the individual elements to be used when making judgements about achievement of the ability. Some of these sub-divisions are themselves compound statements and it could be argued that they need to be further sub-divided. Regardless of whether these sub-divisions are themselves divided, it is necessary to describe the nature of threshold performance against each criterion, sub-division (and sub-sub-division).

For example, consider the ability to 'identify, classify and describe engineering systems'. A threshold descriptor would need to identify the complexity of the system to be described and classified. Performance beyond the threshold would be characterised by the ability to identify, classify and describe more complex engineering systems, or by the ability to describe the system to a range of different audiences or using a range of communication techniques etc. It is now possible to see that performance beyond the threshold cannot be easily or uniquely described, and perhaps the best that can be done is to provide *indicators* of performance beyond the threshold. Indicators for some 'Ability to…Statements' will necessarily be quite loose.

As the *Interim Report* recognises, departments will need to develop grade indicators for levels above threshold level because students expect summative, high-stakes assessments to be reliable across the entire mark range, and not just at the threshold level. Grade indicators (criterion referencing) help to reduce the area of disagreement amongst markers (although continued conversations about shared practices are needed to give the indicators life) and help students to understand better what those markers want and will reward (although they too will need help to understand the meanings behind the wording of the indicators). It is hard to see how assessment practices can lay any claim to reliability in the absence of such clear, understood and used indicators.

There is evidence, mentioned in Section 4 of this report, that engineering teachers find it difficult to develop grade indicators. (Teachers of other subjects also find this difficult.) Again, then, reliability may be better secured with assistance from the AWG or LTSN Engineering Subject Centre (LTSNeng).

It is also important here to note that the articulation of clear ability statements, criteria, threshold descriptors, and grade indicators alone does not lead to valid or reliable judgements. It is crucial for the academic community, and for students, to get together and discuss the meanings of these statements. The discussion needs to be benchmarked with examples of student work and the discussions need to continue until there is an acceptable level of agreement on the judgements made.

These suggestions for improving the reliability of assessment practice are not a miracle cure for reliability problems. On the one hand attempts to produce better criteria or benchmark statements almost always lead to amplification and proliferation, so that simple benchmark statements, such as EPC has produced, accrete hosts of sub-criteria, clarifications and new statements designed to fill gaps that emerge. On the other hand, criteria, benchmarks and rules always have to be interpreted in contexts. Nonetheless, unless actions such as these are taken it is hard to see how, in formal terms, a department could warrant that a student has met any of the 26 'Ability to…Statements'. It could assert it to be the case but unless those achievements were sufficiently reliably assessed, the department ought not to warrant achievement in relation to any of the set of 26. (It goes without saying that for reliable assessments to have much value they need to be valid as well.)

3.4 The place of formative assessments of complex achievements

There is no *requirement* that all learning outcomes be warranted, that they be summatively assessed. The requirement is that they all be assessed in some suitable way because there is a belief that what is not assessed is not valued and a view that assessment can be a powerful aid to learning. On both grounds, then, it is necessary to have assessment arrangements for outcomes that are, in practice, beyond the practical reach of reliable, summative procedures. Formative, low-stakes assessment can be considerably cheaper, which means that resources for higher-reliability assessments can be released by not wasting effort trying to assess reliably complex achievements that tend to resist reliable measurement.

What is envisaged is a formative assessment system in which:

- Many outcomes/abilities/achievements are formatively assessed. This assessment would be low-stakes, designed to give learners useful feedback on how to improve performance against programme-wide criteria. It would be embedded in the learning activities. Student participation in formative assessment would be a requirement for progress through the programme.
- Feedback should be fast, focused, relevant to the assessment criteria, developmental and personal to the student. Reliability would come second to plausibility of judgement, because if a learner felt that a judgement was wrong, then it would be important in the interests of learning for there to be open dialogue about that. This could help to reduce the incidence of the undesirable 'final language' of assessment and generally to reduce the negative emotions associated with the assessment of learning.
- Authentic assessments become easier to manage. The bugbear of authentic assessments has been getting reliability levels that are good enough for high-stakes purposes. Reliability is not such an issue when assessments are low-stakes and the main intention is to promote learning dialogues that inform future work.
- Each programme learning outcome should be complemented by grade indicators, including threshold descriptors, which would give teachers and students a better idea of what would be rewarded
- Students should have the programme criteria from the first, regularly use them, share them, and practise applying them.
- Peer- and self-assessment should be embedded in programmes. Both save teachers time (which can then be used on high-stakes assessment) and help learners to become familiar with programme grade indicators. There have been heroic attempts to devise summative self- and peer-assessment systems but the position here is that they are best kept for formative purposes.
- Information and communications technology can support on-demand self-assessment that can provide feedback and even coaching on points of difficulty.

The value of this formative approach to assessment can best be shown by reference to pages 11–14 of the *Interim Report*. The Civil Engineering 'Ability to…Statements' say graduates should have experience in relation to ten statements and awareness in relation to six. Expressed in these terms, these are 'Ability to…Statements' that resist summative assessment. Students, though, should benefit from plenty of opportunities for formative feedback on work related to these 16 statements. Both teachers and students should benefit from using fuzzy learning criteria or indicators to organise their assessment conversations.

As for the other nine 'Ability to…Statements', departments might wish to invest quite heavily in systematic, programme-wide summative assessment of knowledge (one statement) and ability (eight). So too with the other three engineering disciplines that contributed examples to the Report (pp 15–25), where the different verbs in the 'Ability to…Statements' (discuss, construct, use, make, recognise, carry out, write, appreciate, identify, assess, produce, choose, experiment, derive, test, plan, implement) call for differing approaches to assessment.

Plainly departments could not warrant student achievement in respect of 'Ability to…Statements' that were mainly subject to formative assessment. However, these formative assessment arrangements, combined with a careers and employability support programme, should enable students to lay powerful claims to achievement which they could substantiate with material drawn from the learning portfolios they would keep. (This meshes with the QAA's recommendations on progress files.) Where reliable summative assessments allow departments to warrant achievement, valid formative assessment helps students to lay claim to achievement.

The EPC or the LTSNeng might consider brokering national work on personal development planning, portfolios and progress files to engineering departments, so that they develop efficient systems to ensure that formative assessment contributes effectively to student learning (by identifying ways of doing better) and to their claims to achievement.

Whatever balance is struck between formative and summative assessment, or between coursework and examinations, there would be a need to describe a department's process standards as well. Carter (2001) explains why. Talking of conventional closed-book examinations he remarks that:

> "… even here the nature of the test is determined by how closely the questions set match those which the student may have seen before as exercises or worked examples…That makes it almost impossible for external examiners to make comparisons between the standards in different institutions." (p 3)

Professor Carter is making a point about the degree to which the programme process standards require students to solve novel problems without a high degree of scaffolding[3]. Two similar levels of test performance might reflect entirely different process standards and therefore show two quite different achievements. The one associated with novel test items and little scaffolding would be the one that best fits the EPC output standard. The other would be a better fit with Year 1 work.

Process standard statements would also be important because some abilities will not be summatively assessed and, consequently, departments need ways to assure graduate schools and employers that students are engaged by activities that are likely to lead to the un-warranted achievements to which students will lay claim. These standards could be verified by external examiners or peer reviewers from other departments who should consider whether learning engagements across the complete programme are fit for the purpose of promoting progression. This should ensure that ingredients and processes that are likely to lead to good outcomes are in place and lead us to hope that, on balance, appropriate learning will follow.

The argument is that some achievements can be warranted by summative assessment arrangements. Others are better suited to formative assessment arrangements which help students to learn and make evidence-led claims to achievement. This means that departments need to ensure that students have a range of tasks and other learning engagements that is

[3] Scaffolding is a concept derived from the work of the Russian psychologist Vygotsky (see Duveen, 1997). It indicates that learners have to be supported on their route to autonomy or expertise. This support may involve task design (tasks for novices spell out what needs to be done; those for more autonomous learners expect them to identify the problem and possible solutions); learning support (making helpful resources readily available for novices while expecting more experienced learners to identify for themselves the resources they need); and social support (by letting inexperienced students work together, often under close tutor supervision, while expecting more experienced students to work independently when necessary). These are three forms of scaffolding. We often find that students who can show evidence of similar achievements have experienced different levels of scaffolding. Good assessment systems help employers and graduate schools to appreciate how much scaffolding students have had. Apparent achievements should not, therefore, be taken at face value.

sufficient to stimulate the learning covered by the 26 ‘Ability to…Statements’ – to ensure that programmes contain plenty of learning experiences that should stimulate development in those areas. The quality of these processes – of the tasks, opportunities and engagements – is fundamental to the achievement of output standard. Indeed, employers and graduate schools need to know what these *process standards* are if they are to make good judgements about student claims to achievement. For example, if a programme regularly requires students to gather, reflect on their learning and their future learning needs and act accordingly, then it is reasonable to conclude that claims to achievement in respect of ‘Ability to…Statement’ 2.7(c) are likely to be reasonable. Again, a programme which gives students plenty of advice and guidance to help them succeed on a diet of algorithmic tasks has process standards that are different from another that progresses students to working more autonomously on fresh, authentic tasks.

The QAA’s progress files are to include academic transcripts. The EPC and LTSNeng might consider advising departments how best to provide additional information about the process standards associated with claims to achievement to complement these transcripts. This would identify the learning processes that have been repeatedly used in the degree programme and show how those processes enable new graduates to make good claims to achievement. It would mean teachers telling students to collect evidence of achievements in these areas and include it in their learning portfolios; to benchmark that evidence against programme specifications, which will be inspired by the output standard; to test out the plausibility of their judgements through formative conversations with peers (and with faculty as a part of the programme’s student advisory arrangements); and make claims of achievement to employers and graduate schools that they can confidently substantiate with evidence.

Social measurement theory (Campbell and Russo, 2001) has underpinned the argument that many complex abilities do not lend themselves to affordable and/or reliable assessment. Nevertheless they should be subject to appraisal but formative assessment is more appropriate. Some achievements will be fairly-reliably assessed and will be warranted or certified by the institution. Others cannot be warranted but good formative assessment arrangements will support student learning and their claimsmaking. Out of consideration for those who need to weigh student claims, departments are encouraged to provide statements about their process standards to complement the academic transcripts they will be providing to all new graduates. This is all summarised in Figure 1.

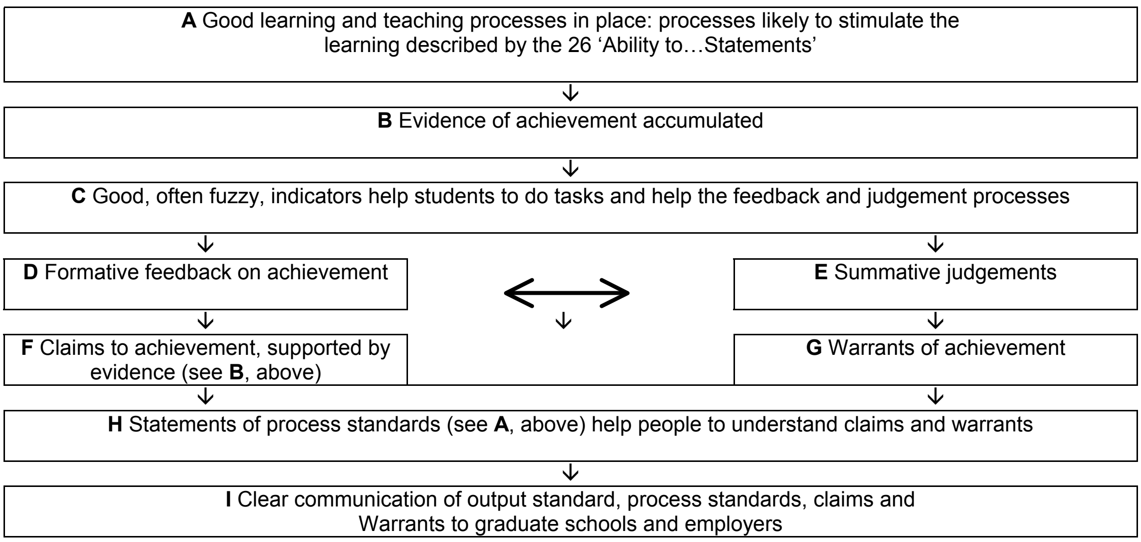

Figure 1. An overview of ‘Ability to’ assessment arrangements

4 Current assessment practices in engineering

In 1998 Dr Norman Jackson, then of the Quality Assurance Agency, published an account of a detailed study, done with the EPC's support, of the development of a specification for a departmental quality management framework for engineering departments (Jackson, 1998).

Drawing on data from seven departments, he reported that:

- Amongst a wide range of views about the purposes of assessment, there was a convergence of views amongst the participants that assessment is primarily to assess learning and secondarily to assist learning.
- Most departments use problem-solving exercises.
- Final projects were set in all participating departments and accounted for between 17% and 23% of the final year marks. However, project aims do not explicitly identify the full range of qualities, skills and attributes that the project is intended to develop. Similarly, marking schemes do not always acknowledge the full range of qualities, skills and attributes that academics take into account when they are evaluating performance.
- Essay assignments feature in the assessment regimes of three departments but are only used in the early stages of the course in two.
- Design tasks, computer-based exercises, oral presentations, laboratory/workshop reports and group projects feature in the assessment regimes in all departments but the frequency of use and overall contribution of marks varies considerably.
- Work-based learning and assessment is featured in three [out of seven] departments. Less used methods of assessment include: multiple choice tests, short answer questions, oral tests, fieldwork reports, learning portfolios, student led seminars.
- Coursework contributed between 14% and 60% of final module marks. There is no consistent trend in the pattern of examination and coursework through the BEng. programmes.

Three points of significance for the EPC's Output Standard project can be drawn out of Dr Jackson's findings:

1. Engineering departments are using assessment methods that are fit for the purpose of assessing student performance in relation to the output standard.
2. There is no evidence of a systematic, programme-wide approach to assessment, although best assessment (and learning) practice contains comprehensive assessment plans that are demonstrably fit for purpose.
3. There is considerable variety of practice between departments (as well as within departments), which raises further questions about fitness for purpose.

The website maintained by the LTSN Engineering Subject Centre (LTSNeng) (www.ltsneng.ac.uk) reports an abundance of replies to its question, 'What are the top three assessment issues for engineers?' The second most important was 'ensuring learning outcomes and deeper learning are achieved'. This concern is all the more pressing if the learning outcomes are the complex and worthwhile achievements described by the EPC Output Standard's 26 'Ability to…Statements'. Moreover, the same website indicates that engineers are uncertain on a number of more specific issues, each of which bears upon the design of assessment practices that are fit for the purpose of assessing authentic learning outcomes: for example:

- Assessing group work
- Setting and stating levels of achievement
- Achieving a sound coursework-to-examination ratio
- Devising assessment methods that are realistic and relevant
- Providing adequate feedback to students

It was argued in a paper for the EPC's Assessment Working Group (Knight, 2001) that the output standard implies an approach to assessment with the following characteristics:

- A systemic, programme-wide approach to assessment;
- Summative, grade-bearing assessment of those outcomes that can be reliably and affordably assessed ;
- Greater use of formative assessment, especially for output standards that resist summative assessment;
- The orchestrated use of a range of assessment methods.

Dr Jackson's findings and the LTSNeng report suggest that good practices are in place *and*, taking heed of the four points above, that there is much to be done to establish coherent assessment practices that are fit for the purpose of assessing 'Ability to' achievements. The LTSNeng also pointed out something that practising academic staff know well, namely that teachers are already hard-pressed, with excessive working loads being a regular shared concern.

4.1 The AWG survey of May 2001

With such points in mind the EPC's Assessment Working Group (AWG) undertook a further survey around Easter 2001 in order to check whether Jackson's picture held true for engineering departments in general and to get a better idea of points of tension in current assessment practice. The belief was that good information on these points would help the AWG to formulate realistic assessment advice that capitalised on best practices already in currency amongst engineering teachers.

Forty-eight responses were received. The most common assessment techniques were identified, and the main findings were:

- All informants used examinations, emphasising their importance in providing secure judgements of individual attainments. (There are lively concerns about plagiarism in coursework.)

- Time-constrained tests, often done in lectures, were reported by almost half the informants.

- Virtually all informants used project work and reports of project work to assess students.

- Three quarters referred to presentations.

- Just over half of the informants mentioned using laboratory reports for assessment purposes.

- Design studies were specifically identified as powerful assessment methods by about a quarter of respondents.

- About a quarter praised *viva voce* examinations or other oral investigations as searching appraisals of understanding and good safeguards against plagiarism.

- A similar number valued assessment by poster presentation.

This is reassuring because these are assessment methods that need to be used if the range of achievements subsumed under the 26 'Ability to…Statements' is to be appropriately assessed. As one informant said,

> "The methods employed currently are perfectly adequate. They provide for a variety of assessments and allow both formative and summative feedback. The methods have evolved over a number of years and are still being enhanced and improved. I would expect to be looking continually at what we do and how we do it and developing new strategies as we move along."

There is expertise in the community of engineering teachers. The task is to ensure that it gets sufficiently distributed, although the report also noted that:

- There are other good assessment methods that informants did not mention. (See Hounsell et al (1996), for example.)

- There are no data on the quality of assessment practices. It is possible to use a method badly, perhaps by trying to use it for a purpose to which it is not well-suited.

- The survey provides no information about scaffolding – the amount of help and guidance students have. The output standard implies that graduates will be able to show 'Ability to' in situations where there is not much scaffolding. It is not clear how far current assessment practices prepare students for this.

More seriously, the EPC Output Standard is a *programme* standard, which implies that assessment needs to be understood as a coherent, programme-wide process. Furthermore, the 'Ability to…Statements' are derived from an analysis of what engineers do and, as such, they are authentic. With authenticity goes complexity; and complex learning goals imply assessment practices that are true to complexity, rather than ones that reduce complexity in the interests of ease or cost. However, a significant point emerging from the survey was that informants attached a lot of importance to examinations because they are reckoned to provide uncompromised information about individual achievement. Some added to this the claim that these methods provide objective and reliable information about individual attainments. Unfortunately, the output standard relates to complex achievements that tend to resist reliable (or reliable *and* affordable) judgement. Informants' emphasis on reliable and secure assessment is in some tension with the need for *valid* assessments of complex learning. The essential questions are:

1. How is it possible to have reliable assessments of achievements as complex as those described by 'Ability to…Statements' 2.7b, 2.4d, 2.2a, 2.1, etc?

2 Are the costs of increasing the reliability of tolerably-valid assessments of complex achievements sustainable?

The survey established that extra demands on engineering teachers such as the demands of revising programme assessment practices so as to align them with the authentic 'Ability to…Statements' would test a system already in tension. Informants identified a number of contributors to this state:

- The prime contributor was the semester system. No-one had anything good to say about it. Complaints were that it led to a bunching of assignments, that scripts had to be marked to tight deadlines, leading to what one person called severe time compression.
- Reference was also made to fragmentation and to the difficulties of scheduling complex and authentic assessments in semester-long courses (by the time students have learned enough to be able to tackle complex assignments there is not enough time left for them to undertake them). Opportunities for formative assessment could be similarly restricted.
- Time was widely felt to be in short supply. Improved quality assurance procedures, tightening up double marking practices, for example, added to pressures on time.
- New assessment methods were valued but seen as costly, particularly in the sense of demanding a lot of time (for students to do them and for teachers to mark them).
- Large classes and rising student numbers have exacerbated tensions.
- More valid assessment methods often made it harder to detect plagiarism.

It was also pointed out that the output standard is a threshold standard, which means that teachers need to derive from it grade indicators for above-threshold performances (3rd, 2:2, 2:1, 1st) and that this is inherently hard, doubly so given widespread unfamiliarity with this necessarily-technical language of learning outcomes. The survey report therefore concluded that while elements of appropriate assessment practice are in place in the engineering community, considerable help should be offered to those trying to devise coherent and valid programme-level assessment practices appropriate to the 'Ability to…Statements'. Informants offered suggestions for improving practice, such as:

- Greater specificity and clarity about assessment practices, expectations and criteria.
- Fewer conventional examinations.

  "I do feel that our main problems within the HE sector is the invalidity of assessments, and the wild belief in the reliability of unseen examinations (even when there is research to show their ineffectiveness in predicting professional success)."
- More formative and less summative

  "…it's the formative assessment that really helps students to learn".
- More collaborative and group assessments.
- Enhanced, substantial design assignments.

  "I would like to see more emphasis on integrative project work and less on syllabus content. This would generate the diversity which the engineering sector needs. The change in emphasis in assessment would be to enhance the 'Ability to…Statements' in the higher levels of taxonomies such as that of Bloom etc. It would also be more motivational, if initially more challenging, to the student cohort."
- Doing more to emphasise and assess non-engineering skills, especially communication, planning and management skills.
- More oral assessment.

- The introduction of personal development records, which are also known as portfolios or records of achievement.
- Assessment need not be so radically different from that currently deployed. It could require both students and staff to work collaboratively.

  > "One example in my department is an examination in which students are posed a brief and incomplete outline of a problem. Working initially in groups, but then individually, they use the invigilator as a consultant to obtain further student specified data to define the problem before moving to propose and justify solutions."

As for the AWG, it might contribute by:

- Continuing to provide examples, illustrations and clarifications of good practice in relation to the assessment of the output standard. The ten points listed immediately above might be elaborated and documented for use by engineering teachers who are attracted by the possibilities but lack sufficient expertise to capitalise on them.
- Advising on assessment techniques, notably the formative use of portfolios, that have considerable potential in the assessment of the output standard.
- Helping departments to work through the implications of synergising assessment techniques that are fit for the purposes defined by the 'Ability to…Statements' and arranging them within a programme assessment plan that promotes progression and coherence in student learning.
- Contributing to raised awareness of assessment purposes and practices, and of their strengths, costs and limitations, so that teachers do not frustrate themselves by trying to devise reliable tests of abilities that are inherently resistant to reliable measurement.

In short, empirical work with EPC members suggests that while the output standard raises a number of practical problems, it is possible to envisage fair and worthwhile assessments of its twenty-six 'Ability to…Statements', assuming that best thinking about assessment is deployed. It should be appreciated that engineering departments will need sensitive help if they are to engage successfully with what will often be substantial changes to infuse their programmes with best assessment practice.

5 Practical assessment methodologies appropriate to the output standard

Section 4 listed eight assessment techniques that may be well-suited to the 'Ability to…Statements', while noting that:

- They are not universally used;
- There are tensions that inhibit many engineering teachers from doing a great deal to align their assessment practices with those implied by the output standard;
- Module-level assessment reform is not sufficient for the purpose of warranting achievements of students across a programme, nor for helping their learning across the undergraduate years, nor for helping them to make strong claims to achievement.

5.1 Examples of assessment practice and barriers to change

There is a great deal that can be done to disseminate these module-level examples of appropriate practice. The survey of EPC members at Easter 2001 was not designed to provide detailed examples of such practices, although some contributions indicated that there are plenty to be collected, for example:

> *Communication exercises*: "Oral or written or visual presentations. Usually encountered in the context of other civil engineering activities and seen as valuable transferable skills [output standard 1.2.1]…Such exercises are time consuming for staff and students, especially marking of written work. Objectivity of marking is not easy to guarantee. We have attempted to produce a graded performance scale…by giving a clear description of the qualities one would expect to associate with any particular band of marks. In principle this can provide an opportunity for self/group/peer/staff criticism and be very positively formative."
>
> *Design project:* "Students work in groups of 3 or 4 and are asked to indicate the distribution of effort among the group to aid eventual award of [individual] marks…the projects are very open-ended, allowing students to apply a subset of the technical skills they have acquired over the previous three years. Assessment is through a preliminary written report, an oral presentation, a final written report and a poster presentation … grading criteria are provided…Each project has two supervisors and there are usually two assessors. This activity is time consuming and the assessment is time consuming [but] it counts heavily towards the final degree."
>
> "…eliciting and clarifying clients true needs [output standard 1.2.2(a)] might best be assessed by observing performance in a simulated interview; whereas the ability to produce detailed specifications of real target systems could be assessed in a written examination."

By itself, disseminating examples of good practice will not be enough to align assessment regimes with the demands of the output standard. In part this is because teachers want help to work out how to adapt good practice to their particular situations, but it is also because they are short of time, juggling multiple roles and operating in departmental and institutional environments that may not be conducive to fresh assessment practices. For example, although the case for formative assessment is compelling (Black and Wiliam, 1998), those wanting to promote it at the expense of summative assessment are likely to encounter resistance from others who have strong beliefs about assessment that actually fly in the face of the science of social measurement (Campbell and Russo, 2001). This analysis recognises that there may be a shortage of common knowledge about good assessment methods and that teachers are under pressure and short of time to innovate.

Anything that simplifies the burden of innovation will be a welcome contribution to the hard-pressed potential innovator. So too will be the appearance in 2002 of Professor John Heywood's *Curriculum, Instruction and Leadership in Engineering Education, Part II*. (The first part has just entered very limited circulation but it is the second part which reviews the international literature on assessment in engineering.) However, there are deeper difficulties that proponents of the output standard need to confront. A toolkit of assessment methods suited to the output standard is not enough.

5.2 Understanding the materials: the need for good assessment theory

One of the biggest challenges to the establishment of assessment regimes that serve the output standard well is the prevalence of common-sense notions of what assessment is. Carter (2000) says that:

> "It is a commonplace of Engineering that any statement of requirements (requirements specification) is incomplete without a test specification. The argument is that any requirement which is not capable of being tested or verified in some way is meaningless."

This tends to produce the conclusions (a) that there must be objective and reliable measures of the requirements or specification and (b) that any assessment procedure which falls short is therefore defective and a waste of time and effort. Leave to one side the objection that where complex and indeterminate outcomes are concerned, the best that can be done is to ensure that good process standards are in place and trust that they will tend to have effects in the desired direction: instead, consider the objection that all assessment, especially where human thinking and doing are concerned, rests on judgement of available evidence. There are a few cases where judgement may be akin to measurement but, in general, human thinking and doing are not susceptible to measurement, only to good judgements. As Hamer (2001) puts it:

> "What much recent work on assessment has indicated is that the gold standard [examining and testing techniques] is not quite as refined as was commonly believed: that there are not quite as many things we can assess with certainty as was once thought, and that those that we can are not necessarily the most worthwhile or useful. This is helping to free up thinking."

Quite simply, good practice in the assessment of engineering achievements depends on recognising that the view of assessment as measurement is an impoverished one. Successful dissemination of the EPC Output Standard may be tied up with re-forming common-sense notions of what assessment is, what it can do and how it can do it.

5.3 Approaches to developing appropriate, practical assessment methodologies

The first thing to accept is that changing practice requires time and effort. It will involve some costly re-shaping of the way academics think about assessment and how they *design* assessment methods. However, it will not necessarily lead to more complex, time consuming or expensive assessment *practices*. With good leadership and understanding, it can lead to better, rather than more assessment methods. Some methods may well be new, others will result simply from modifying existing methods to ensure greater alignment with the output standards.

Five approaches are discussed in this section. It is for the community, either within a particular engineering department, or nationally, to determine which particular approach or approaches will work best for them.

5.3.1 Analysis of existing practices

The eight most common assessment practices in engineering were identified in Section 4. These can be summarised as: examinations; time-constrained (class) tests; project reports; presentations; lab reports; design studies; vivas or orals; and poster presentations. The interesting thing here is to note that this list identifies *how* the students are being tested, rather than *on what* they are being tested. An effective analysis might consider each of the common assessment methods in turn and determine their effectiveness in measuring a student's achievement against each of the seven 'Ability to…Statements'. This might lead to a 7 x 8 matrix as below:

	1 key skills	2 systems to models	3 conceptual to determinable models	4 obtain system specifications	5 physical models	6 create real target systems	7 critically review performance
exams							
class tests							
project reports							
presentations							
lab reports							
design studies							
vivas/orals							
posters							

Thus, for example, project reports might be effective in assessing set 4, a student's ability to use determinable models to obtain system specifications. (This includes mathematical modelling, use of standard software platforms, sensitivity analysis, critically assess results and improve performance.) Design studies might be effective in assessing a student's ability across all of the 'Ability to…Statements'.

5.3.2 Analysis of 'Ability to…Statements'

This approach simply turns the grid the other way round. The analysis begins with the 'Ability to…Statements' (this could include all of the 26 sub-statements) and, for each statement, identifies effective assessment methodologies for the abilities to be appraised. This analysis provides an opportunity to go beyond traditional assessment practices in university engineering departments and consider methods by which engineers are evaluated in employment or methods used in other academic disciplines.

In considering the two analyses above, it is possible to identify assessment methods which are effective across a large range of the 'Ability to…Statements' and to distinguish these from methods which are only effective for a small range of statements. In this way, the analysis may well identify redundant assessment methods. The analysis could also be extended to consider other criteria for determining effective assessment methods: for example, cost and time demands.

5.3.3 Analysis of existing assessment criteria

This analysis shifts the focus from how students are assessed to what they are assessed on. The output standards may relate most closely to the final year of a student's programme, so this analysis would identify all of the assessment tasks students undertake in their final year and, for each one, lists the assessment criteria being used. These criteria can then be easily mapped to the sub-statements in the output standards that will show where there is over-assessment and where there are gaps in the assessment.

This form of analysis is, perhaps, better than the first two, as it focuses on what is being assessed, rather than on how. It also shows the degree of 'coverage' of the 'Ability to…Statements'. Again, it is possible to turn the analysis through 90 degrees and to begin with the output standards and map them to the assessment criteria.

5.3.4 Assessment strategy for a programme – leading to a map

The first three approaches (sections 5.3.1 – 5.3.3) provide useful information on existing practice. However, they analyse what *is*, rather than begin by thinking about what *ought to be*. An alternative approach would begin with the output standard for a programme of study and go on to consider how the student might be given the opportunities necessary to:

- develop these abilities;
- provide evidence of having achieved these abilities.

This leads to a top-down, systematic and systemic approach to both programme design and to an assessment strategy. The first bullet point (development of abilities) gets a programme team thinking about the modules that need to be in a programme and how programme learning outcomes will be distributed so as to support the output standard. The second bullet point (provision of evidence) leads the team to the identification of an assessment strategy which operates across the full set of modules. This improves the chances of ensuring (a) that all of the 'Ability to…Statements' are assessed and (b) that none of them is over-assessed. It is also likely to lead to a more uniform learning and assessment environment for the student – but it *may* require large changes in practice from the status quo and therefore meet resistance from hard-pressed academic staff.

5.3.5 Assessment practices beyond engineering

In Section 4 the eight most common assessment methods were identified. It also presented further findings by Jackson in regard to ways of improving current methods or introducing new methods. Key suggestions included collaborative or group work, enhanced design exercises, integrative project work, Personal Development Records or Records of Achievement and staff collaboration. Jackson's (1998) work also reported pleas for clearer criteria and formative uses of assessment (to improve learning).

The development of an assessment strategy, as discussed above, should lead to staff collaboration in assessment and to a reduction in assessment overload. Introducing clear criteria and standards indicators should improve the reliability and even the validity of assessment and an analysis of existing assessment methods, as also discussed above, should lead to better validity. Indeed, an assessment strategy should be able to bring together assessment methods that were previously used independently of each other.

It could be argued that assessing something as complex as the output standard *requires* a harmonised approach, which might bring together such methods as project or design reports, and oral presentation and a poster presentation. Some universities use this bundling of assessment methods (with the further inclusion of a question and answer session) to assess the final year project. What is being suggested here is not the discrete use of a range of methods, but a harmonised, strategic approach to assessment. Matters would be further helped by the application of the 'Ability to…Statements' as criteria for assessment.

If we go beyond engineering education, we discover other assessment methods used in other subjects that might well translate to engineering and may even be more effective in assessing the output standard. These methods include crits in Architecture or Art and Design, public enquiries in Legal Studies, problem based learning and assessment in Health and Nursing, portfolios and records of achievement in a range of other disciplines, and negotiated assessment in work-based learning programmes. The ASSHE Inventory (Hounsell et al, 1996) reviews these and many other assessment techniques that EPC members might wish to consider in the context of the assessment of the output standard. The set of booklets published by LTSNgc is also helpful (Generic Centre, 2001).

However, effective, reliable assessment begins, not with the assessment method, but with a careful description of what it is that the assessment is attempting to assess (the criteria and standards).

5.3.6 Good programme design

The programme specification guide summarised in Annex B (Moore, Wolverhampton) is devised to encourage good programme design. Notable in the guide is the requirement to identify the programme design tools in Section 7. These should include an appropriate output standard or range of output standards in engineering programmes. Section 10 identifies the programme outcomes, which arise from the design tools, and the student learning activities and assessment methods to be used. Section 11 provides the opportunity for the programme design team to determine an assessment strategy at each level of study. It is at level three (final year) that the strategy should be mapped to the output standard. This is where the programme team can optimise assessment, harmonise assessment methods across the modules and encourage collaboration between module tutors and academic teams in devising an appropriate range of assessment methods. The generic criteria identified here also ensure better validity and reliability. Section 14, although still very general, affords the opportunity to map the output standard to the assessments in each module.

5.3.7 Good module design

The module specification guide summarised in Annex C (Moore, Wolverhampton) is intended to encourage good module design. The programme design team identifies the learning outcomes necessary for the student to achieve all of the programme outcomes, which in turn arise from the output standard. This ensures that the modules are contributing directly to attainment of the standard. Having articulated these learning outcomes at module level, the guide provides a methodology for identifying the learning activities and assessment strategy for the module.

There is a clear focus on identifying the criteria by which judgements can be made about a student's attainment of the learning outcomes and on describing the threshold standard for each criterion. This reductionist approach may belie the complexity and fuzziness of assessment, but it provides a much clearer starting point for assessment, and it provides a language for those who judge student achievement in which they can discuss their judgements.

5.3.8 Calibration: the need for grade indicators

Although the output standard has examples of the meanings that the 'Ability to…Statements' can take in four engineering disciplines, there is, as some Easter 2001 survey informants said, a need for more detailed guidance on what would count as evidence of threshold performance on each of the 26 statements. Whether the EPC takes up the job or not, departments adopting the output standard would also need indicators to help them tell students about the characteristics of performance beyond the threshold, indicators that they would also use to make good, differentiated judgements of achievement.

The word indicators is used here rather than descriptors as it is not possible to pre-specify all forms of achievement in a determinate way. Fuzzy indicators are the right sort of indicators for some achievements, although when it comes to the assessment of information retention, tight performance descriptors can be specified. Carter and Neal (1995) have provided an example of a semantic scale that they use to help them make good judgements of postgraduate projects. Similarly, the words 'beyond the threshold' are used to indicate that higher achievement can be evidenced in at least two ways. Threshold descriptors establish the range and level of performance required to meet the 'Ability to…Statements'. Higher performance can be characterised either by evidence of additional abilities (beyond those identified in the standard) or by higher levels of performance (beyond the threshold) which lie within the standard.

6 Work in progress and next steps

6.1 Using tools and templates: the 2002 summer workshop

The generation of the 'Ability to…Statements' that make up the EPC output standard was only the beginning of a process that has not yet been completed. The work of the AWG has concentrated on identification of the issues associated with assessment of the output standard but implementation of the output standard is broader than just assessment. The Assessment Working Group regards this report as an Interim Report because it has not proved possible to complete all the work which the Working Group believes to be required in the time available.

In particular, the Working Group is convinced of the need for specific examples of successful practice in using the EPC Output Standard as the primary point of reference in programme design and specification. It therefore intends, subsequent to publication of this report, to mount a five-day intensive Assessment Workshop for academics with programme-design responsibilities in collaboration with LTSNeng. The purpose of the workshop is to explore, test and gather successful practice in assessment of achievement against the EPC Output Standard and in the use of the Standard in programme specification. The outcomes of the Workshop will subsequently be incorporated into the Final Report of the Assessment Working Group.

The workshop is intended for 32 teachers from sixteen engineering departments to help them to apply some of the thinking about the assessment of the output standard, contained in this report, to their own degree programmes. Not only will they establish good practices in the assessment of 'Ability to…Statements', but also their work on programme specifications will be a resource for others in the national community of engineering teachers. These 32 teachers will constitute a pool of experts on engineering assessment and can act as consultants to their colleagues. The link with LTSN is seen as extremely important to the subsequent dissemination of good practice. The flyer describing the initial announcement of this workshop is included in Annex D.

6.2 External examiners

Despite Carter's observation (noted above) that external examiners have limited power to compare standards, they are still important commentators on departmental practices and should have access to information about the processes that underlie the assessments. The AWG could help colleagues with the assessment of 'Ability to…Statements' by working directly with external examiners. This would probably be done in association with LTSNeng.

6.3 Journal editors

Benefit might be gained from working with editors of those engineering journals that incline to publish papers on learning, teaching and assessment. Dissemination of ideas for effective practice in assessment to support the output standard is important.

6.4 Collaboration with LTSN Engineering Subject Centre (LTSNeng)

Recently the OSCG has seen the need to further co-ordinate EPC work with the Learning Teaching Support Network for Engineering (LTSNeng) whose goal is to 'provide high quality information, expertise and resources on good and innovative learning and teaching practices and to effectively promote and transfer such practices to enhance learning and teaching activity in UK Higher Education'. EPC believes that its Output Standard presents significant opportunities for rethinking the delivery of engineering teaching and learning in Higher Education and that the use of output standards has substantial implications for the assessment of engineering HE. It therefore welcomes the prospect of closer collaboration with LTSNeng where interests overlap.

6.5 Working with employers

Those responsible for employing engineering graduates may not be sufficiently clear about the status of the output standard in relation to other statements of engineering competence and may also have some rather restricted views of what can be assessed and how. They may be prone to the measurement fallacy; to the belief that all achievements can be measured if only sufficient care is taken with test design, administration and marking.

It is not easy to see how a groups such as AWG can have much influence with a very diverse and distributed set of employers but it is clear that employers do need to understand the output standard and associated assessment processes. Reassuringly, the output standard, based as it is on an analysis of what engineers need to do, should be easier for employers to understand than some other standards that come from less valid sources. Furthermore, our thinking about the assessment of the output standard calls for a reporting system that is clear and refers to real engineering achievements, and is not dependent on abstract numerical arrays.

It is clear that, at the least, the AWG should take steps to make employers aware of the realities of assessment.

6.6 Further work in progress

EPC has taken steps to inform and to learn from international experience by undertaking a full programme of participation in European and international conferences related to standards, learning and assessment in the context of engineering.

7 Conclusion

The AWG has been looking at the implementation of the output standard in a systematic and well-informed way. Concluding that implementation is feasible and worthwhile, it has recognised that educational expertise as well as common sense would be called for. That educational expertise has informed its thinking and helped shaped the approach to assessment that has been outlined above, especially in Sections 4-5.

Existing assessment practices promise well for the implementation of some aspects of this scheme but there are also gaps and obstacles. In other words, neither the AWG's enthusiasm for the output standard approach, nor its identification of an assessment system fit for the purposes intrinsic to the output standard, is sufficient. If not the AWG, then some other EPC body will have to take some responsibility for what all experts in the field recognise to be a difficult, uncertain and costly phase: implementation. Although simple and straightforward innovations may have small implementation costs (and sometimes they turn out to be less straightforward and a lot more expensive than imagined), others, such as the output standard, which try to encourage complex achievements of worth, do not. They are expensive of time, ingenuity, patience, skill and goodwill and often of money as well, although there can be long-term savings to offset several years of implementation costs.

If the EPC wants to see the output standard project achieve its potential, it must recognise that social innovations are only successfully implemented with care; it ought then to plan to support implementation. The AWG has begun to do this, seeing, for example, the need for:

- Collaboration with the LTSN Engineering Subject Centre, which has funds and networks that can be invaluable for implementation processes that will last for, say, five years.
- Enhancing engineering teachers' capacity for dealing with these profound and important practical educational issues. In 2002 this will take the form of a summer workshop, details of which are in Annex D.
- Working with colleagues in engineering departments to produce tools to help in assessment development: tools such as programme and module design guides (Annexes B and C); reports of good practices, such as those that will emerge from the Summer workshop; and, perhaps, a compendium of assessment methods in engineering on the lines of the *ASSHE Inventory* produced by Hounsell et al (1996).
- Action on a number of other fronts, as sketched in Section 6.
- Work with employers to help them to appreciate how the output standard can help them and how they can help the EPC to help them through the Standards implementation.

The Assessment Working Group (AWG) shares the view of those who drew up the EPC output standard that it is a concise and valuable representation of engineering practices with the potential to enhance considerably engineering education in the UK. It is particularly timely, given the implications of the Bologna Declaration for undergraduate engineering programmes and UK developments, such as programme specifications, progress files and the emergence of a new quality enhancement system. These developments call for output standards that encourage deep learning and help undergraduates to learn a subjects distinctive concepts, skills and practices, all the while growing as autonomous people capable of working fluently with others.

The AWG has had to appraise the practical qualities of this exemplary standard – to ask whether it can be implemented, given the human and physical resources available to UK engineering departments. It is well known in social and educational research that implementation is far from simple (as proponents of evidence-based practice are now finding: Pawson, 2001a, b), takes time and resources (Fullan, 1991), and adds its own twists and turns to policies and standards (Fullan, 1999). Implementation questions are, then, important ones to ask of the output standard.

The AWG has concentrated on one facet of implementation, the feasibility of assessing achievement against the standard. There are those who reckon assessment questions are the most important (for example, Brown and Knight, 1994), which means that the AWG's work has concentrated on possibly the most significant facet of the implementation question.

There is no attempt to conceal the size of the challenge. In the 1990s, the British government, acting through the National Council for Vocational Qualifications, invested heavily in the development of National Vocational Qualifications which were intended to assess and report on the achievement of complex vocational competencies. It became clear that this is no straightforward matter and that assumptions about achievement, judgement and measurement needed to be re-created (Edwards and Knight, 1995). It also became clear that good, valid standards and the assessment systems that mesh with them imply enhancements to teaching, learning and curriculum practices as well. Discovering this cost tens of millions of pounds.

The AWG has taken these discoveries seriously and concludes that if the engineering community combines its best assessment practices with this knowledge of how competence can *and cannot* be assessed, then world-class assessment practices can be put in place along with the output standards, always given that there are sufficient resources to implement both properly.

The following concluding statements can be made about the AWG approach to assessment:

1. It is based on social measurement theory and best knowledge about the assessment of complex achievements.
2. It is designed to support an authentic output standard that values complex achievements.
3. It recognises that engineering is a process or way of thinking, rather than just the ability to re-present a body of knowledge.
4. It recognises that the assessment of authentic and complex achievements is a programme-wide concern and must be seen as a move away from module-level thinking about assessment matters.
5. It recommends that assessments be distributed across a programme in order to end the common situation in which some achievements are over-assessed while others, especially in the soft skills, are neglected.
6. It complements QAA thinking on progress files.
7. It is supported by AWG plans to provide exemplar material and other help for programme leaders.
8. It is novel, evidence-led and feasible. Like all best practice, some will also find it demanding.
9. It is a model of good practice from which other subject areas can learn.

8 References and resources

It is a pity that most of the resources to help colleagues in the assessment of the output standard are ones that the engineering community needs to develop for itself. The nearest to an off-the-shelf resource is Heywood (2000). Although this is very definitely about assessment in general, Heywood's first profession was engineering and his examples are often drawn from engineering education. The same is true of Cowan (1998), although this is a book about teaching first, assessment second. The ASSHE inventory (Hounsell *et al.* 1996) and the Generic Centre's dozen booklets on assessment (Generic Centre 2001) have already been recommended. Other standard works on assessment include Black (2000), Boud (1995), Brown, Bull & Pendlebury (1997) and , Walvoord & Anderson (1998).

8.1 References

Black, P. (2000) Research and the development of educational assessment, Oxford Review of Education, 26 (3&4), pp. 407-419.

Black, P. and Wiliam, D. (1998) Assessment and classroom learning, *Assessment in Education*, 5(1), 7-74.

Boud, D. (1995) *Enhancing Learning through Self-assessment*, London: Kogan Page.

Brown, G., Bull, J. and Pendlebury, M. (1997) *Assessing Student Learning in Higher Education*. London: Routledge.

Brown, S. and Knight, P. (1994) *Assessing Learners in Higher Education*. London: Kogan Page.

Campbell, D. and Russo, (2001) *Social Measurement*. Thousand Oaks, CA: Sage Publications.

Carter, R. (2001) A framework for the specification of degree programmes in engineering. Lancaster: unpublished paper.

Carter, R. and Neal, B. (1995) Assessing competence in engineering project management, in: A. Edwards and P. Knight (Eds.) *Assessing Competence in Higher Education*. London: Kogan Page, pp.123-132.

Cowan, J. (1998) *On Becoming an Innovative University Teacher*. Buckingham: Open University Press

Dalziel, J. (1998) Using marks to assess student performance, Assessment and Evaluation in Higher Education, 23(4), pp. 351-366.

Duveen, G. (1997) Psychological development as a social process, in: L. Smith, J. Dockrell and P. Tomlinson (Eds.) *Piaget, Vygotsky and Beyond*. London: Routledge, 67-90.

Edwards, A. and Knight, P. T. (1995) *The Assessment of Competence in Higher Education*. (London: Kogan Page).

Engineering Professors Council Working Party on Assessment (1992) *Assessment Methods in Engineering Courses*. London: Engineering Professors Council.

Fullan, M. (1991) *The New Meaning of Educational Change*. London: Cassell.

Fullan, M. (1999) *Change Forces: The sequel*. London: Falmer.

Generic Centre of the Learning and Teaching Support Network (2001) *Assessment Series (twelve booklets)*. York: Generic Centre of the Learning and Teaching Support Network

Hamer, J. (2001) Assessing output standards. Paper presented to the EPC Congress April 2001.

Hamer, J. and Macintosh, H. (2000) Engineering assessment in 2020: reconciling the irreconcilable? Paper written for the Assessment Working Group of the Engineering Professors Council.

Heywood, J. (2000) *Assessment in Higher Education*. London: Jessica Kingsley Publishers.

Heywood, J. (2001) *Curriculum, Instruction and Leadership in Engineering Education, Part I*. Dublin: Division of In-service Education, Trinity College.

Hounsell, D., McCulloch, M. and Scott, M. (Eds.) (1996) *The ASSHE Inventory* (Edinburgh: University of Edinburgh and Napier University).

Jackson, N. (Ed.) (1998) *Pilot Studies in Benchmarking Assessment Practice*. London: the Quality Assurance Agency.

Knight, P. (2001) *The Assessment of EPC Output Standards*. Lancaster: Unpublished paper (available on request from p.knight@lancaster.ac.uk)

Knight, P. and Yorke, M. (2000) Tuning the undergraduate curriculum. Lancaster, unpublished paper http://www.lancs.ac.uk/users/edres/research/skillsplus/index.htm

Pawson, R. (2001a) *Evidence Based Policy: 1. In Search of a Method*. London: UK Centre for Evidence Based Policy and Practice, Queen Mary, University of London.
Pawson, R. (2001b) *Evidence Based Policy: II. The Promise of Realist Synthesis*. London: UK Centre for Evidence Based Policy and Practice, Queen Mary, University of London.
Walvoord, B. E. and Anderson, V. J. (1998) Effective Grading: A tool for learning and assessment. San Francisco: Jossey-Bass.

Annex A

Working Group Membership, Acknowledgements and Terms of Reference

The Working Group met five times between 19 January 2001 and 4 January 2001and wishes to thank the Royal Academy of Engineering for its generous support of facilities for group meetings during this time. Thanks are also due to Tim Feest, Director of OSCEng, for help with editing and formatting of the report for printing.

The Working Group comprised :

David Muir Wood – Chair	University of Bristol
Fred Maillardet	University of Brighton, EPC Committee
Peter Knight	University of Lancaster
Tony Ward	University of York
Ivan Moore	University of Wolverhampton
Fiona Lamb	Learning Teaching Support Network Engineering
Tim Whiteley	EPC Project Officer

The aims of the project are :

1 To support engineering departments in the development of effective and efficient assessment processes appropriate to the implementation of EPC Engineering Output Standard.

2 To promote the use of the EPC Engineering Output Standard and, where appropriate, other nationally-agreed output standards.

It was originally envisaged that work on the project would proceed as follows:

Stage 1: A review of current assessment methods and identification of good practice as it relates to engineering

Stage 2: Evaluation in terms of validity, reliability, utility and efficiency of current assessment methods in relation to their use with the EPC Engineering Output Standard

Stage 3: Formulation of guidance on assessment strategies and practices for use with the EPC Engineering Output Standard.

Annex B

Programme specification guide
(courtesy of Ivan Moore, Wolverhampton University)

1 Title of programme
2 Awarding institution
3 Teaching institutions (indicate any collaborative links/partners)
4 Programme accredited by
5 Final award
6 UCAS code (undergraduate programmes)
7 Descriptors and generic criteria being used to define the programme outcomes (eg QAA qualification descriptors, level descriptors, key skills, subject benchmarks, etc). These should be attached to the document
8 Educational aims of the programme:
9 Employment opportunities:

10. The programme provides opportunities for learners to achieve the following outcomes:	11. The outcomes are achieved and demonstrated through a range of teaching, learning and assessment methods including:
A. Knowledge and understanding of:	Learning and teaching students learn by:
	Assessment
B. Subject specific skills able to:	Learning and teaching students develop subject specific skills by:
	Assessment
C. Intellectual skills able to:	Learning and teaching students develop intellectual skills by:
	Assessment
D. Key skills able to:	Learning and teaching students develop key skills by:
	Assessment

12 Structure of the programme: Show the modules which go to make up the programme of study. Indicate core, core option and elective modules or lists as appropriate.
Level 3
Level 2
Level 1

13 Module details: List the learning outcomes for each of the core modules and the common learning outcomes for the core option lists identified in section 12.
Level 3
Level 2
Level 1

14a Assessing knowledge and understanding: Use the table below to identify which core/core option modules will *assess* the knowledge base identified in section 10A.

Module code	Knowledge and understanding			

14b Assessing subject-specific skills: Use the table below to identify which core/core option modules will *assess* the different subject-specific skills identified in section 10B.

Module code	Subject-specific skills			

14c Assessing intellectual skills: Use the table below to identify which core/core option modules will *assess* the different intellectual skills identified in section 10C.

Module code	Intellectual skills			

14d Assessing key skills: Use the table below to identify which core/core option modules will *assess* the different key skills identified in section 10D.

Module code	Key skills			

Annex C

Module specification guide
(courtesy of Ivan Moore, Wolverhampton University)

1 Parent programme (the programme for which the module is designed)
2 Module title
3 Level
4 Credit rating

Description of the module
5 Educational aims: The module aims to…
6 Outcomes: On completion of the module, the student is expected to be able to…
(If this is a core or core option, transfer these outcomes to section 13 of the *Programme specification template*)
7 Range statement: Give a description of the content to be included in the module or the content of the topics to be studied:

Contribution to programmes of study
8 Explain why and how this module makes a necessary contribution to the learning opportunities provided by the parent programme:
9 In what ways might this module contribute to programmes other than the parent programme?

Design parameters and tools
9 Descriptors and generic criteria being used to define the programme outcomes (eg QAA qualification descriptors, level descriptors, key skills, subject benchmarks, etc). These should be provided for validation and available to students.
11 Describe the source of evidence for the effectiveness of the assessment and student learning activities (eg books or other publications – give references, student evaluations, previous experience, research).

Learning activities
(Note the learning outcomes for a core option module should be the same as those for all the modules in the core option list.)
12 In order to achieve the learning outcomes, the students will be engaged in the following learning activities. (Identify both in-class and out-of-class activities. For in-class, identify the range of classes [lecture, tutorial, seminar, practical, workshop, etc].)
13 What evidence do you have that the learning activities described above will be effective in helping students to achieve the learning outcomes?

Assessment
14 The learning outcomes will be assessed using the following methods (show weightings):
15 Explain why you consider these assessment methods to be both valid and reliable and how they will support the students in their learning.

Assessment
16 Indicate which learning outcomes in section 6 are to be assessed by each assessment method in section 14.

Learning outcome	Assessments			

17 For each of the learning outcomes listed in 6, describe the criteria which will be used to make judgements and the standards to be set for each criterion to achieve the relevant grade. (Use one table for each learning outcome defined in the module.)

Learning outcome						
Criteria	Threshold grade					
	F	E	D	C	B	A

Resources

18 List the recommended texts, initial sources of electronic reference material, and other information sources to be used. If these resources do not currently exist, then indicate how and when they be made available.

19 Explain how you will be using technology to support the students in this module. If you do not intend to use technology, then justify this decision.

20 Describe other learning resources which are necessary for the students (eg WOLF, study skills support, laboratory or other equipment, external expertise, etc). Indicate whether these are needed for learning or for assessment. Indicate the teaching accommodation which will be required and the nature of its use. If any resources do not currently exist, then indicate how and when they will be made available.

Annex D

'Output Standards and Assessment Workshop' for Undergraduate Programme Directors in Engineering departments

The Engineering Professors' Council has consulted widely in developing output standards for Engineering degrees. It recognises that these standards, like the QAA benchmark statements, invite Engineering departments to re-appraise their programmes and practices. This need for reappraisal is particularly acute when it comes to assessment matters, as EPC members said in response to a survey done in April 2001.

The EPC, working with the Engineering Subject Centre of the LTSN, wants to help programme directors and others with responsibility for undergraduate teaching to develop approaches to assessment which are not only sound and practical but also more efficient in terms of the use of staff and student time. These approaches should produce a good alignment between programme goals (as represented by EPC Output Standard and by other points of reference such as SARTOR3 and QAA benchmarks), teaching practices, learning tasks and the assessment arrangements themselves.

Because this is a complex operation, the EPC and Engineering SC intend to offer this *Output Standards and Assessment Workshop* as an extended, practical and developmental activity to a limited number of programme directors (or Heads of Department and others with major programme design responsibility) who will benefit by working together on real and pressing problems of programme design.

By the end of the workshop programme, each participant will have:

1. Used evidence of best practice and drawn on the EPC Output Standard (and other points of reference) to review the programme specification for one of the participant's undergraduate programmes;
2. Become aware of the range of procedures and purposes for assessing student achievements, especially those achievements described by the EPC Output Standard;
3. Begun to design programme-wide assessment arrangements to allow student achievements, particularly those expressed in terms of output standards, to be recorded;
4. Reviewed the links between the output standards, the learning and teaching environment, and the assessment arrangements in programme design;
5. Taken account in these design activities of constraints and of opportunities to achieve efficiencies in assessment, learning and teaching practices.

The workshop will run between March-November 2002 as follows:

- There will be five days of face-to-face work with electronic communication before, during and after these meetings.
- A one day meeting in March will clarify priorities and identify pressure points. It will include orienting presentations on programme specifications, the EPC Output Standard and assessment possibilities and practices. Workplans will be agreed in preparation for the August residential workshop.
- A residential workshop on August 6-8 will combine input from practitioners and researchers with expertise in the field of assessment, teaching and curriculum in engineering with collaborative but individualised work to develop efficient programme specifications that embody best assessment practice in respect of complex learning outcomes. Sustained problem-working, discussions and critiques will lead to the production of feasible assessment plans that align with programme specifications that refer to output standards and other appropriate points of reference.
- The workshop will conclude with a review, refinement and dissemination meeting in November 2002. It will consolidate work done in the light of comments from HEI departments/colleagues and identify strategies for the most effective dissemination of what will have been achieved by workshop participants.

Report of the Employers' Working Group

The EPC Engineering Graduate Output Standard

An employer-group interpretation

January 2002

The Engineering Professors Council

Published by
The Engineering Professors Council
Secretariat: c/o Institution of Mechanical Engineers
1 Birdcage Walk
London SW1H 9JJ
England

Printed in England by
Training Publications Ltd
Watford

Contents

Summary

The Employers' Working Group was set up in the summer of 2001 to give a first industrial view of the Output Standard produced by the Engineering Professors' Council.

The Group welcomed the standard as a means of providing recruiters with more detailed information on the individual abilities of engineering graduates to supplement the classification of the degree awarded. The Group found no obvious omissions or irrelevant elements within the standard, however this report details two areas in which it is thought further consideration could be given to make the standard more useful and user friendly for the non-technical recruiter.

Suggestions to strengthen the emphasis on key skills, particularly team working, together with some modifications to the language used to describe the abilities achieved by the graduates, is included in the report. This report also clearly indicates those areas in which it is thought that the standard would be particularly beneficial to employers. The report concludes with recommendations for the promotion and effective communication of the standard as a means of closer co-operation between employers and academia.

1 Introduction

In response to the Dearing Report and other external pressures, the Committee of the Engineering Professors' Council (EPC) set up a working party in 1999 to investigate the establishment of a generic Output Standard for all engineering schemes. Phases I and 2 of the work were completed and published as an Interim Report entitled EPC Occasional Paper Number 10, December 2000. The Standard consists of a framework of twenty six 'Ability to…Statements' expressed in generic non-discipline-specific terms, based upon the procedures adopted in solving an engineering problem. A key principle of the work was that the Output Standard defines an expectation of all the engineering attributes.

In adopting this principle, recognition was given to employers' legitimate requests to know what they might expect of a graduate emerging from a United Kingdom university with an engineering degree. In the age of elite Higher Education this expectation had been met by the degree classification system which was essentially a norm-referenced ranking system. However, in the present mass system of higher education, norm-referenced systems provide insufficient information on individual students' abilities to new employers and in particular to SMEs, who have become significant recruiters of engineering graduates.

Phase 3 of the work was subsequently approved to consist of five linked sub-projects, one of which is concerned with the views and expectations of employers recruiting engineering graduates. The overall aim of this sub-project was to clarify industries' needs and expectations in relation to the EPC Engineering Output Standard and to encourage the use of the standard by employers. This report outlines the main areas discussed by the Employers' Working Group, the outcomes from those discussions and recommendations.

2 Background

The procedure for entry into the engineering industry for graduates is normally one where the individual's A-level grades determine admittance to university and course and where the classification of the degree awarded is a key determinant of employment. In effect, therefore, all the employer gets is a 'rank' with no clear idea as to the achieved abilities of the applicant. The Working Group was unanimous in its view that a move to help address this and to provide more objective information to prospective employers was to be welcomed.

Though all businesses differ, there was a high degree of consensus within the Working Group that in addition to the 'technical' skills acquired by engineering students during their University course there was an increasing need for, and expectation of, other 'key' skills and personal attributes. Today employers need young people with good oral and written communication skills, with the ability to work with others across disciplinary boundaries, to be capable of presenting their 'case' to management and to be willing, able and industrious learners.

Assessing these key skills and personal attributes in addition to technical skills is the responsibility of the 'recruiting' team in a company. Because of the huge variation in size and recruiting needs, the processes employed vary enormously; from a formal 'assessment centre' that may take several days, all the way through to a relatively uninformed personal interview conducted by a person with little knowledge or understanding of engineering. It was clear to the Working Party that whatever the recruiting process, there would be genuine merit in having more objective information about the 'output' from our engineering courses. This information would not only assist selection but would also help identify those gaps that a graduate training programme should address.

Amongst the employing organisations of the Working Group members and other employers which the Working Group consulted, there was an expressed view that there was a gap between the abilities of graduates and the 'input' abilities desired (and expected) by employers. In particular, the increasing importance of 'key skills' did not appear to be matched by an increased emphasis on developing these abilities during engineering degree programmes.

Members recognised that changes in secondary education, particularly in mathematics and the sciences, has meant that universities have found it necessary to spend time in strengthening these basic requirements for engineering. The additional burden of enhancing graduates' key skills implies additional resources which university departments may not have at their disposal. Given the importance that industry attaches to these key skills there is a need for a debate on the funding of this work.

3 General Observations

3.1 Initial consultation and modification of Terms of Reference

The Working Group (Annex A) agreed the Terms of Reference (Annex B).

The first task was to establish:

- Whether employers agreed that an 'output standard' was beneficial ;
- What utility such a standard would have for employers;
- Whether there were any serious omissions from the standard;
- Whether there were elements of the standard that should be deleted as inappropriate.

The consultation (see Annex C for list of employers consulted) elicited the following broad consensus:

- The Output standard would be beneficial to employers in a number of ways (see below);
- There were no obvious omissions or erroneous inclusions;
- The language in which the output is expressed is less than clear, especially to non-engineers (and recruiters are not usually engineers);
- There was concern that there was much too little attention and emphasis given to the acquisition of key skills and in particular to the growing importance of team-working skills. This is referred to in our recommendations. (Some members expressed the view that a knowledge of another European language would be beneficial).

In the light of these responses, the Working Party modified its Terms of Reference to exclude reference to the development of benchmarks and to focus on assessment of the clarity and inclusiveness of the primary and secondary 'Ability to…Statements'.

3.2 Benefits to employers of adoption of the EPC Output Standard

It was considered important that the benefits to employers (and to universities) of application of the standard should be made explicit in this report. It is in the application that the end user, the employer, can get an improved return on their investment through a better-targeted and more-focused recruiting process and through the in-company training that should be complementary to the work students have done at university. These benefits were:

- In recruitment processes – to have confidence that those universities that have adopted the standard will provide students with the stated abilities;
- Being able to use the 'Ability to…Statements' during 'technical' interviews in the recruitment process to highlight deficiencies;
- In the design of 'assessment centres' – to be able to define more sophisticated discriminators knowing that key abilities have been met;
- Allowing company training schemes to be more carefully designed as a continuation of the students' university work, thereby enhancing the benefit of the programme and giving companies a more professional image with students;
- Incorporating the standard into training programmes will allow the programmes to be more focused on the needs of the business and not cover skills already acquired;
- Employers having the knowledge that students from Universities that have not signed up to the standard can not be assumed to have these abilities.

4 Proposed revision to the wording of the EPC Output Standard

In addressing the concerns about the phrasing of the standard the Working Group proposed the following re-drafting of the EPC Standard. However, it is to be noted that it was not the intention of the Working Group to suggest changes to the underlying 'substance' of the standard.

4.1 Key Skills

The ability to exercise key skills is expected of all engineering graduates and these should be encouraged and developed during the degree course. These are:

- Communication
- General IT user abilities
- Application of number
- Working with others (including Team Working)
- Problem solving
- Improving own learning and performance

In addition to the above, which are recognised nationally as Key Skills, the Working Group considered that graduates should also demonstrate attributes of drive, motivation and innovation.

4.2 Proposed re-drafting of the EPC Output Standard

4.2.1 Ability to understand an engineering problem and see it in its context

This means the ability to:

(a) Clarify customer's needs;
(b) Identify and classify engineering systems (together with components);
(c) Define the problem in terms of performance specification, objective functions and constraints;
(d) Be aware of social, legal and environmental impacts, in the setting of constraints.

4.2.2 Ability to identify those concepts relevant to the problem

This means the ability to:

(a) Consider alternative concepts and their features;
(b) Resolve difficulties created by imperfect and incomplete information.

4.2.3 Ability to use these concepts to evaluate solutions

This means the ability to:

(a) Use appropriate skills (mathematics, computing, engineering) to create a range of theoretical solutions;
(b) Identify key parameters, limitations and merits of the solutions;
(c) Summarise merits and limitations and select best option.

4.2.4 Ability to specify the selected solution to the engineering problem

This means the ability to:

(a) Evaluate theoretical solutions using a range of inputs and constraints;
(b) Critically assess results and if necessary improve knowledge database and refine solution;
(c) Generate optimum specifications within national and international standards.

4.2.5 Ability to realise the specified solution

This means the ability to:

(a) Select appropriate production methods;
(b) Negotiate contracts relevant to the specified solution;
(c) Implement production and deliver products fit for purpose, on time and within budget;
(d) Operate within relevant health and safety and environmental frameworks.

4.2.6 Ability to evaluate the solution and ensure it meets the specified requirement

This means the ability to:

(a) Verify that the real system complies with the specification and meets the customer requirement;
(b) Assess whether the real system has achieved the planned cost/benefit analysis;
(c) Assess whether the real system has adequately addressed environmental, social and ethical issues.

5 Recommendations

1 It is recommended that the EPC Output Standard Project endorse the revised specification of the standard.

2 It is recommended that further work is done on benchmarks to ensure alignment with the revised specification of the output standard.

3 It is recommended that careful consideration be given to an effective communication of this standard to employers. The value of the EPC exercise will be much greater if there is broad awareness of the standard amongst employers.

4 The importance of 'team-working' cannot be overemphasised and it is recommended that the EPC explore ways in which this vital skill can be developed during an undergraduate's time at university.

5 It is strongly recommended that the production of this output standard is not treated as a 'one-off' but as the start of a process that brings the university sector and employers closer together in terms of human capital development and that the EPC should broker this.

Annex A

Membership of Employers' Working Group and acknowledgements

The Working Group met formally three times between 14 August 2001 and 15 November 2001and wishes to thank the Royal Academy of Engineering for its generous support of facilities for group meetings during this time. Thanks are also due to Tim Feest, Director of OSCEng, for help with editing and formatting of the report for printing

The Working Group comprised :

James Davies	Corus Strip Products
Derek Dring	Filtronic plc
Alan Hearsum	Glass Training Board
Martin Hogg	Thales plc
Louisa Porter	Corus Strip Products
Erica Tyson	Rolls-Royce plc
Paul Watts (Chairman)	Marconi plc
Derek Spurgeon	EPC Co-ordinating Group Chairman
Ajit Shenoi	EPC Committee representative

Annex B

Terms of Reference

1 To clarify industry's desire for and expectation of the Engineering Output Standard; to determine significant omissions in the existing Standard and agree appropriate changes in content where necessary to reflect the needs of employers.

2 To report progress to the EPC Committee through the EPC Output Standard Co-ordinating Group.

3 To produce a final report on the outcomes from the Working Group for the EPC Output Standard Co-ordinating Group.

Annex C

Consultation with individuals involved in the recruitment process:

Dr John Dean	Technical Director, Filtronic Components Ltd
Dr Alison Hodge	QinetiQ plc (formerly DERA); also chair of CEng Committee; Institute of Physics.
Joanne Dodge	Personnel Manager, PACE MicroTechnology (reporting comments from three senior engineers).
Dr Robin Corlett	Senior Project Manager, Filtronic Components Ltd. (Milton Keynes).
Dr Wolfgang Bosch	Head of Global Technology Group, Filtronic Comtek (Shipley) Ltd.
Tom Arnold	Engineering recruitment & Training Manager, Filtronic Comtek (Shipley) Ltd.
Prof John Roulston OBE	Director of Technology, BAE Systems (Avionics Group).
Mr J CarrSenior Manager)	Quality & Training), Landis Lund.
Darren Race	Training Advisor, Filtronic Compound Semiconductors Ltd.
David Wright	Training Manager, CHASE Advanced Technologies.

Other contacts:

Corus CC&I including Engineering Business colleagues (CNES)
Corus Research (Swindon Laboratories)
Engineering Council (article published in EnVoxPeople)

Report of the IEng Working Group

The EPC Engineering Graduate Output Standard

Exemplar benchmarks for IEng

January 2002

The Engineering Professors Council

Published by

The Engineering Professors Council
Secretariat: c/o Institution of Mechanical Engineers
1 Birdcage Walk
London SW1H 9JJ
England

Printed in England by

Training Publications Ltd
Watford

Contents

Executive Summary

1 The IEng Working Group (IEngWG) was set up in April 2001 by the Engineering Professors' Council (EPC) to generate exemplar benchmarks for IEng degrees and to test the validity and applicability of the EPC Engineering Graduate Output Standard for this kind of degree.

2 The Working Group set out to achieve this aim by:

- Seeking views on whether the 'Ability to…Statements' of the EPC Engineering Graduate Output Standard contained in the Interim Report [EPC, 2000] of the EPC Output Standards Project, and illustrated there by example applications to CEng degrees, are equally applicable to IEng degrees.

- Devising discipline-specific benchmarks for these statements, exemplifying the threshold level appropriate for all graduates aspiring to eventual Incorporated Engineer status.

3 Six sets of illustrative benchmarks have been developed by five different universities covering the disciplines of Civil, Electrical & Electronic, Mechanical and Mechatronic Engineering, and these are detailed in Section 6 of this report.

4 It was found that the framework of 'Ability to...Statements' provided by the EPC Engineering Graduate Output Standard is equally applicable to benchmarking for IEng as for CEng. That is, the Standard can be used to define the expected abilities, at an appropriate threshold levels, of graduates from programmes intended for both CEng and IEng aspirants.

5 In drafting the benchmarks, it was found that short interpretive statements qualifying the high-level 'Ability to...Statements' in particular discipline contexts often assisted clarity.

6 The Working Group found that the EPC Standard provides a language and a framework which enables discussion and comparison of expected engineering graduate abilities across the disciplines benchmarked in the report. It also facilitates discussion of the key similarities and differences in the abilities on graduation of Chartered Engineers and Incorporated Engineers.

7 The essential and differing characteristics of Chartered Engineers and Incorporated Engineers are stated in SARTOR 3 and are discussed further in this report.

8 The Working Group found that the language provided by the EPC Standard and the process of benchmarking helped to illuminate the key differences between IEng and CEng degree programmes. The differences lie both in the content of the programmes and in the type of support employed during programme delivery.

1 Background

1997 was an eventful year for UK Engineering Higher Education. Not only did it see the publication of the report of the National Committee for Enquiry into Higher Education (the Dearing Report) [HMSO,1997] and the establishment of the Quality Assurance Agency (QAA) but also the publication of the Engineering Council's Policy Document 'Standards and Routes to Registration – 3rd Edition'[Engineering Council 1997], more commonly known as SARTOR 3 . The latter set out the Engineering Council's intentions regarding the criteria for future accreditation of engineering degree courses as providing the appropriate educational base for registration as an engineer.

1.1 EPC response to SARTOR 3

A feature of the criteria was the use of minimum engineering-course input standards defined in terms of A-level points scores.

The Engineering Professors' Council (EPC) was convinced that the best graduates from UK Engineering Degree courses were, by any measure, as good as ever and compared favourably with the graduate engineers of our international competitors. However, it shared some of the Engineering Council's concern regarding an increasingly 'long-tail' of those graduating from traditional 'CEng' engineering courses, usually with lower degree classification, who proved to have relatively modest achievement and capability in coping with the theoretical and mathematical challenges which they presented. SARTOR 3 also introduced the concept of an alternative and different type of degree course (the 'IEng degree') aimed at bringing out the talents of those students who were more practically inclined. Nevertheless, EPC was opposed in principle to the routine use of A-level scores (and their vocational equivalents) at input to a degree course as a proxy for engineering ability and potential at the output.

1.2 Employer perceptions of engineering graduates

Concurrently, EPC had been aware of a growing and increasingly-articulated perception amongst some employers that the HE system was not producing enough engineering graduates with the skills and attributes they required. Employers wanted graduates of excellence in two distinct categories: firstly, those to contribute to driving the technology forward; secondly, those with more practical awareness who were primarily needed in the running of projects within the limits of current technology. On the other hand, members of EPC Committee, through their work as examiners, accreditors and quality-auditors, believed that there continues to be many excellent engineering courses producing many good graduates who compare favourably with graduates from other disciplines and with engineering courses in other countries.

Although many of the negative comments imputed to some industry and government bodies were not supported by evidence to show that this view was widespread and valid, EPC recognised that perceptions are frequently as important as the reality. It seemed likely that a contributory factor in the apparent contradiction was a mismatch between the expectations of graduate capability of employers on the one hand and HE on the other. In the absence of agreed engineering graduate output standards, resolution of this mismatch seemed problematical.

1.3 EPC Output Standard Project

To address the related issues of Engineering Council educational requirements and the apparent mismatch of expectations, EPC decided to undertake a project to establish standards for engineering graduates at the output of their engineering degree course - the EPC Output Standard Project, which started in 1998.

1.4 'Ability to...Statements'

Following widespread consultation both within Higher Education and with other key stakeholders such as employer organisations and accrediting bodies a standard was produced, defining the expectation of the attributes of all engineering graduates in terms of 26 generic statements of graduates' 'Ability to...'. These statements formed the essential framework of the EPC Standard describing what all graduates must be able to do but were insufficient on their own to describe the level of the expected ability. It was intended that the level of activity within the framework of 'Ability to...' should be exemplified by illustrative statements from providers of engineering degree courses which would then, following normal processes of peer review, come to provide an agreed picture of a reasonable expectation of the abilities of all engineering graduates. Such statements were (and are) referred to as exemplar benchmarks.

1.5 Benchmarking the EPC Standard

The standard and methodology was validated by nine 'pilot' universities who developed benchmark statements for a range of their engineering programmes in the main engineering disciplines. All but one of the sets of benchmark statements were intended to illustrate the threshold level of BEng programmes intended primarily for those aspiring eventually to Chartered Engineer but one university benchmarked its MEng programme, providing examples of statements describing a threshold at MEng level. This illustrates one of the fundamental strengths of the EPC Output Standard : the generic 'Ability to…Statements' provide a framework describing what all engineering graduates must be able to do, which individual programmes can then benchmark to describe and communicate the intended threshold level. It was originally intended that the normal processes of peer review would consider benchmark statements from a range of programmes and disciplines and would eventually generate a consensus about the appropriate threshold level for BEng programmes within the framework of the EPC Output Standard. However, the emergence from the 'pilot' benchmarking process of a set of MEng benchmarks implies that the methodology might, by a similar process of benchmarking and peer review, also be used to establish a threshold level for MEng programmes.

1.6 Incorporated Engineer Working Group

It was believed that the same approach might also be used to establish a threshold level for programmes designed to meet the needs of those aspiring to Incorporated Engineer (IEng degrees for short) and this view was strongly supported by employer organisations and Incorporated Engineer professional bodies. The IEng Working Group (IEngWG) was set up to generate exemplar benchmarks for IEng degrees and to test the validity and applicability of the EPC Engineering Graduate Output Standard for this kind of degree. It was proposed that this aim should be achieved by:

- Seeking views on whether the 'Ability to…Statements' contained in the Interim Report, and illustrated there by example applications to CEng degrees, are equally applicable to IEng degrees.

- Deriving benchmark statements, within the existing 'Ability to…' framework, illustrating the intended level of outcome for a representative range of IEng programmes.

- Advising on the adaptation of the existing 'Ability to…Statements' to the context of IEng, should this course of action prove to be unavoidable.

The EPC Standard itself, its rationale and development, and exemplar benchmarks from the pilot universities are described fully in 'The EPC Engineering Graduate Output Standard – the Interim Report of the EPC Output Standards Project' [EPC, 2000].

2 Methodology

The IEng Working Group comprised members from six universities with a strong interest in the provision of degree programmes designed specifically to meet the educational needs of young people aspiring to become Incorporated rather than Chartered Engineers. A representative range of engineering disciplines was chosen within the limits of the group size.

The group examined the exemplar benchmarks which had been developed specifically for students graduating from CEng degrees [EPC, 2000] and members wrote benchmarks illustrating the threshold appropriate to graduates emerging from their existing IEng degree programmes. In some cases attempts were made to write benchmarks for both CEng and IEng graduates side by side to try to establish and illustrate the primary differences between them and between the two kinds of corresponding educational experience.

As benchmarking progressed it became clear both that the EPC Engineering Graduate Output Standard provided an appropriate framework for describing the expected abilities of graduates from IEng programmes and that it was possible to formulate benchmarks which illustrated the desired threshold level of those abilities for all those graduating from particular IEng courses. Nevertheless, it also became clear that the clarity and accessibility of the exemplar benchmarks could often be enhanced by the inclusion of brief interpretive statements qualifying the high-level 'Ability to…Statements'.

The benchmarks generated by Working Group members are set out in detail in Section 6 of this report. In reading these and the EPC Output Standard (Section 5), it is very important to note that ability in the area of Key Skills is regarded as being of the greatest importance to all engineering graduates [EPC, 2000], regardless of whether they aspire to Chartered or Incorporated Engineer. The very first 'Ability to…Statement' of the EPC Standard is 'Ability to exercise Key Skills in the completion of engineering-related tasks at a level implied by the benchmarks associated with the following statements'. Therefore implicit in all the exemplar benchmarks of Section 6 is ability in the Key Skills defined nationally [QCA, 2000] as Communication, IT, Application of Number, Working with Others, Problem Solving, Improving own Learning and Performance developed in the context of the specifically-engineering benchmarks.

These Key Skills abilities have not been explicitly defined in any of the exemplar benchmarks but any eventual consensus within the HE Engineering community about engineering benchmarks will need to include benchmarks to illustrate the expected level for Key Skills abilities to match the first 'Ability to…Statement' of the EPC Standard.

3 Discussion

3.1 Comparison of characteristics of Incorporated and Chartered Engineers

The working party recognised that there are differences in the educational processes within IEng and CEng degree programmes, and that the graduates emerging from such programmes do possess, in a number of areas, different attributes and skills.

SARTOR 3 sets out the roles and responsibilities of both Incorporated and Chartered Engineers and specifies the requirements for the educational base of each, relating them to criteria for course design. Incorporated Engineers are envisaged as the backbone of the engineering profession, acknowledged for their competence in practical engineering situations, and often required to turn innovative ideas into working reality.

This theme has been revitalised following the emergence of the Engineering and Technology Board as the successor to the Engineering Council. In its influential report to Lord Sainsbury, 'Making the Best of Valuable Talent' the Hawley Group [Engineering Council, 2000] recommended that :

> 'There should be a sharper focus on the characteristics of Incorporated Engineers, with the aim of building their image and status. They should be portrayed as clearly different, and clearly equal to Chartered Engineers. The message at present is confused and until this is corrected, perceptions will not change'.

The Working Group found the table below to be a useful, although perhaps over-polarised, starting point for describing the differences between Incorporated and Chartered Engineers and, by implication, the different strengths which need to be developed during their formation. As the Hawley Group suggests, the two types of engineer are to be regarded as different but equal in esteem.

Chartered Engineer	Incorporated Engineer
Emphasis on Understanding	Emphasis on Know-how
But needs appropriate know-how	But needs appropriate understanding
Top class innovative engineers – vision and judgement	Top class applications engineers – vision and judgement within field
Mathematical modelling/understanding of theory and IT	Needs to apply appropriate maths, science and IT
Designs beyond limits of current practice	World leaders at working within current technology
System orientated	Continued quality of products and services
Research	Applied research and development
Seeks fundamentals for future solutions	Transforms today's knowledge in applications
Medium to long-term perspective	Short to medium-term perspective
Adept at team management with prospective promotion to middle/top management	Adept at team management with possible promotion to middle/top management

Overlap in Mobility and Employment

These differences were, in part, reflected in the discussions of the working party. A set of CEng benchmark statements, included as Annex C to this document, has been prepared for Mechanical Engineering in order to facilitate comparison of the perceived differences and indeed also the similarities between the two types of engineer.

3.2 Benchmarking IEng degrees

It was agreed that there were few problems in writing illustrative benchmarks for IEng degrees within the framework of the EPC Output Standard as defined by the original 'Ability to…Statements', without any need for their explicit modification. However it was considered that, in some cases, such benchmarks would benefit from the inclusion of short interpretive statements or caveats to be associated with the high-level statements and placed immediately after them.

Such statements, which are to be regarded as a legitimate component of the benchmarking process, would be used to interpret or clarify the benchmarks so as to fit the very diverse range of engineering disciplines which are emerging for IEng and, if necessary, to adapt them more transparently to the original 'Ability to…Statements'.

Illustrative benchmarks have been developed by five universities and are included in this report. They cover Civil Engineering, Mechanical Engineering, Electrical and Electronic Engineering and Mechatronics.

In some of these, writers have found it helpful to replace 'Ability to' in a selection of the benchmarks by 'awareness of' or 'knowledge of' or 'experience of' so as better to reflect the differences between IEng and CEng. When used in benchmarks in this way, to illustrate or imply level, the meaning of these terms is determined to some extent by context and consensus and is not precisely defined. In others the complexity of the tasks specified in the benchmarks differ from the CEng equivalent.

For instance under 'Ability to transform existing systems into conceptual models' an IEng Mechanical Engineering graduate may be expected to identify, classify and describe the key physical parameters which…at a level of complexity equivalent to, for example a simple two-speed gearbox. The corresponding CEng benchmark may consider a multiple variable speed gearbox (SHU comparison). In a similar way the exemplars used may involve greater mathematical expectation for CEng graduates. On the other hand in some practical areas the IEng graduate may be expected to possess the more advanced skills. The practical use of a modern CAD package, for example, may require the IEng graduate to produce more sophisticated and detailed output drawings than those expected from a CEng graduate, although the CEng graduate may be more involved in defining the original specification and parameters of the task.

An emphasis on application, implementation and construction or production has been introduced in some areas. This is not intended to imply any difference in quality of the work of IEng students but rather reflects the nature of the work performed.

The IEng graduate is expected to work within the limits of current technology whereas for a CEng one would expect some degree of creativity and innovation and a broader commercial perspective to be evident even at the benchmark threshold. This does not mean that the IEng graduate is incapable of 'creativity and innovation' but that it would not be expected at the threshold. At a higher level of achievement than the threshold, one would expect the IEng graduate to be just as creative as their CEng counterpart, within the scope of their own activity.

3.3 Differences between degree programmes for IEng and CEng

The final issue concerns the differing natures of programmes of Higher Education targeting those aspiring to IEng and to CEng. CEng programmes, in general, require the student to take more responsibility for their own learning: that is, to be more self-directed, incorporate greater emphasis on the theoretical and analytic aspects of the design process and to be challenged by open-ended problems. IEng programmes, by contrast, are more tutor-directed and expect that students will be asked to address problems which, though equally demanding in many ways, are not so open-ended.

This point raises the issue of the supporting framework provided during the programme delivery. The emphasis of the CEng course is on provision of a thorough understanding of engineering theory and its application to problem solving and the CEng student should be stretched in these respects. For instance, in relation to the project, CEng students are expected to be largely self-directed and capable of recovering on their own from an inauspicious beginning. By contrast the IEng course is designed to provide a thorough understanding of current technology and its application to practical problems; the IEng course project should therefore be more biased to supporting the development of more practical know-how and may therefore need earlier intervention and greater guidance in this respect.

The nature of the support within a programme and the assessment of that programme are closely linked and both affect the expectations described within the benchmarks. Thus some of the example benchmarks for IEng contain statements such as ‘some guidance may be required to compensate for experiential shortfalls’; or ‘guidance may be necessary due to limited practical knowledge’.

4 Conclusions

The conclusion of the working party is that the EPC Output Standard, in the form of a series of ‘Ability to…Statements’ to be applied at the time of graduation, is equally applicable to IEng degree programmes as to programmes accredited for CEng, except in the level of ability needed in each statement: in the statements more allied to theoretical understanding there will be a lower requirement for the IEng graduate, whereas in those statements more concerned with practical applications the requirements may be higher. The standard therefore forms a sound basis for further work on the assessment of IEng engineering graduate output standards. It also provides a language which permits and encourages discussion at a generic IEng level across differing engineering disciplines.

5 The EPC Engineering Graduate Standard

5.1 The nature of the Standard

The EPC Standard takes the form of a list of 'Ability to…Statements'. The list is given in Section 5.3 and some of the terms used are defined in Appendix B.

The level of expected attainment to be associated with the Standard is described by attaching a Benchmark statement to each 'Ability to…Statement'. Examples of engineering discipline-specific benchmarks are given in Section 6 for the discipline-specific areas of Civil, Electrical & Electronic, Mechanical and Mechatronic Engineering. Each applies to a threshold level of attainment for graduates from programmes of study designed for those aspiring to eventual Incorporated Engineer. It is to be emphasised that the threshold level indicated by the benchmark examples is that which is appropriate specifically at the point of graduation, not at some subsequent point in a graduate's engineering career.

The 'Ability to…Statements' in Section 5.3 are expressed in generic, non-discipline-specific terms. They are based on the procedures carried out by an engineer in solving an engineering problem and delivering the solution.

Typically an engineer will need to be able to identify and describe the problem that is to be solved, and to do this effectively he will draw on existing engineering systems and the experience of the past. The solution will have a specification with parameters that will require evaluation, a process that relies heavily on the engineering skills of conceptualisation, determinable modelling and analytical representation. Delivery of the specified solution, in a timely and efficient manner, draws on another set of skills that are vital to the engineering process, skills which are likely to include the verification of some conceptual assumptions by experimenting with physical models. Finally the engineer should possess the necessary key skills, be capable of evaluating his or her own performance and be able to identify their learning and future development needs.

The engineering problem-solving process is not a simple systematic procedure involving the mechanical completion of one task after another. Creativity and the application of understanding are involved as the outcome of each procedure influences and changes the assumptions made in other stages of the process. Handling this iteration efficiently in the context of engineering is the hallmark of an experienced engineer. Nevertheless, an engineering graduate would be expected to have an appropriate level of understanding of all of the steps involved in engineering problem solving, and to have recognised the need to develop and apply iterative procedures efficiently.

5.2 Application of the Standard

The Standard is applied to a particular engineering discipline in two steps. The first step is to interpret the generic 'Ability to…Statements' given in Section 5.3 in the context of the specific discipline. The second step is to provide exemplar benchmark statements to describe the level of attainment in terms of the level of skills, knowledge and understanding required for each of the abilities. The benchmark examples given in Section 6 were developed for programmes aimed at providing the educational base for an Incorporated Engineer, and are indicative of the threshold level at which the degree would be awarded. Other engineering degrees in these same disciplines may well find it appropriate to provide different benchmarks to illustrate different emphases and detail within the same framework of 'Ability to…Statements'. The standard provides a language and framework which facilitates this. Provided a sufficient number of engineering degrees use the standard, it is believed that a process of iterative peer review will, in due course, lead to consensus about benchmarks.

Key Skills (Communication, IT, Application of Number, Working with Others and Improving Own Learning and Performance) and abilities associated with professional practice are not directly benchmarked in the Standard. The benchmark statements for the other 'Ability to… Statements' should indicate the level to which the Key Skills are to be developed.

In formulating the Benchmark statements care is needed to ensure that they may be readily assessed. It is expected that traditional written examination and coursework assessment, the Group Design Project and the Individual Project will continue to be the main assessment vehicles for the majority of the benchmarked abilities and Key Skills.

5.3 The Generic 'Ability to…Statements'

The following statements are those which [EPC, 2000] describe the Engineering Graduate Output Standard.

(1) *Ability to exercise Key Skills in the completion of engineering-related tasks at a level implied by the benchmarks associated with the following statements:*

Key Skills for Engineering are Communication, IT, Application of Number, Working with Others, Problem Solving, Improving own Learning and Performance.

(2) *Ability to transform Existing Systems into Conceptual Models*

Ability to:
2.1 Elicit and clarify client's true needs.
2.2 Identify, classify and describe Engineering Systems.
2.3 Define Real Target Systems in terms of objective functions, performance specifications and other constraints (ie define the problem).
2.4 Take account of risk assessment, and social and environmental impacts, in the setting of constraints (including legal, and health and safety issues).
2.5 Select, review and experiment with existing Engineering Systems in order to obtain a database of knowledge and understanding that will contribute to the creation of specific Real Target Systems.
2.6 Resolve difficulties created by imperfect and incomplete information.
2.7 Derive conceptual models of Real Target Systems, identifying the key parameters.

(3) *Ability to transform Conceptual Models into Determinable Models*

Ability to:
3.1 Construct Determinable Models over a range of complexity to suit a range of Conceptual Models.
3.2 Use mathematics and computing skills to create Determinable Models by deriving appropriate constitutive equations and specifying appropriate boundary conditions.
3.3 Use industry standard software tools and platforms to set up Determinable Models.
3.4 Recognise the value of Determinable Models of different complexity and the limitations of their application.

(4) *Ability to use Determinable Models to obtain system Specifications in terms of parametric values*

Ability to:

4.1 Use mathematics and computing skills to manipulate and solve Determinable Models.
4.2 Use data sheets in an appropriate way to supplement solutions.
4.3 Use industry standard software platforms and tools to solve Determinable Models.
4.4 Carry out a parametric sensitivity analysis.
4.5 Critically assess results and, if inadequate or invalid, improve knowledge database by further reference to existing systems, and/or improve performance of Determinable Models.

(5) *Ability to select optimum Specifications and create Physical Models*

Ability to:

5.1 Use objective functions and constraints to identify optimum specifications.
5.2 Plan Physical Modelling studies, based on Determinable Modelling, in order to produce critical information.
5.3 Test and collate results, feeding these back into Determinable Models.

(6) *Ability to apply the results from Physical Models to create Real Target Systems*

Ability to:

6.1 Write sufficiently detailed specifications of Real Target Systems, including risk assessments and impact statements.
6.2 Select production methods and write method statements.
6.3 Implement production and deliver products fit for purpose, in a timely and efficient manner.
6.4 Operate within relevant legislative frameworks.

(7) *Ability to critically review Real Target Systems and personal performance*

Ability to:

7.1 Test and evaluate real systems in service against specification and client needs.
7.2 Recognise and make critical judgements about related environmental, social, ethical and professional issues.
7.3 Identify professional, technical and personal development needs and undertake appropriate training and independent research.

6 Exemplar benchmarks

In each of the sets of exemplar benchmarks 6.1 to 6.6, the first 'high-level' ability, for example 6.1.1, is omitted. This is the benchmark corresponding to Key Skills ability, exemplification of which, although of great importance, is outside the scope the present Working Group.

6.1 Exemplar benchmarked abilities for IEng graduates in Civil Engineering – Nottingham Trent University

The following benchmarked ability statements are appropriate to graduates of the BSc (Hons) degree in Civil Engineering at Nottingham Trent University and are related solely to those abilities demonstrated in the conduct of an Integrated Design Project similar in complexity to these examples:

- Functional and structural design and specification of an underground car park
- The design of an enlarged river lock system for commercial traffic
- Functional and structural design of facilities at a wetland nature reserve, including aspects of access, amenities, bridges and bank management
- The regeneration of a city centre square, managing access, leisure, transport and architectural aspects.

All these projects include elements of survey, research, design, presentation, evaluation, environmental management and legislative requirements.

Such a project is undertaken by final year students working in teams with final and second year students from the BEng (Hons) Civil Engineering degree course. Teams under the leadership, generally, of a final year BEng student are given a project brief and are required to prepare a conceptual design taking into account environmental issues, health and safety and economic considerations. Normally, each team makes a presentation of its conceptual design to the 'Client' who chooses the best designs or combination of best design and submits this as a design brief to the teams. The detailed design work is divided up amongst the team according to ability and specialisms, thereby simulating the actual team structure in professional practice.

Whilst the format of the six generic 'Ability to…Statements' has been adhered to, the creation of physical models including prototype modelling is less appropriate to Civil Engineering and to Incorporated Engineers in particular. However, aspects of foreseeing and planning for social and environmental impacts, and of construction safety for the chosen target system is of particular significance and has been emphasised in the final 'Ability to…Statement'.

Other elements of the course such as Field Courses, Structural Design projects and taught modules would contribute to or add to these benchmark statements. The value of a Supervised Work Experience year as a positive contribution to practical considerations greatly assists in ability development and is an essential characteristic of the Nottingham Trent programme.

6.1.2 Ability to transform existing systems into conceptual models

(a) The graduate has demonstrated the ability to identify and specify a problem or need in terms of its essential components and to search for possible solutions or provisions in a range of existing real target systems, for example observing traffic and pedestrian flows, structural systems and ground conditions and reviewing similar structures or systems to find relevant good examples.

(b) The graduate has demonstrated the ability to survey, measure and classify the identified problem or need in order to produce input parameters for the conceptual model. This includes physical mapping and plan production as well as information surveys by means of literature review and questionnaires.

(c) The graduate has demonstrated the ability to work in multi-disciplinary teams to produce inclusive conceptual models of complex systems; an example would be the production of construction schemes integrating aspects of structures, hydraulics, soil mechanics and environmental control in one proposal. These schemes would be expected to contain the rudimentary elements but may have limitations.

(d) The graduate has demonstrated the ability to use manual and IT-based systems to communicate concepts to other interested parties. For example the production of plans, posters and client presentations using manual and computer-based drawing and presentational methods.

6.1.3 Ability to transform conceptual models into determinable models

(a) The graduate has demonstrated the ability to select components or constructional methods appropriate to the conceptual model. An example would be the selection of ground support systems such as retaining walls where access, ground conditions and environmental matters influence the choice of appropriate methods. Some guidance may be required to compensate for experiential shortfalls.

(b) The graduate has demonstrated the ability to use graphical, intellectual and IT skills to assemble appropriate components into a feasible solution to the problem or need. For example this might include the selection of beam and column sizes to economically fit traffic layouts in a car park.

(c) The graduate has demonstrated the ability to select appropriate design methods for the analysis or modelling of components or assemblies of components within the conceptual model. Examples would be the application of straightforward theory and design codes to hydrostatic, hydrodynamic, foundation and structural components of the design. Some errors in the model may be expected.

(d) The graduate has demonstrated the ability to choose constructional materials appropriate to the conceptual model and understand the consequences of such choices for fire, loading, life span and maintenance. Some guidance may be required to compensate for experiential shortfalls.

(e) The graduate has demonstrated the ability to communicate with clients and other interested parties in order to determine the conceptual model most appropriate to the needs of the client or commissioning agent; for example by giving presentations and submitting reports.

6.1.4 Ability to use determinable models to obtain system specifications in terms of parametric values

(a) The graduate has demonstrated the ability to use mathematical, IT and graphical skills to solve determinable models and to produce specifications for the manufacture or construction of components, assemblies or spatial configurations within the real target system. For instance, this might include the production of drawings and construction details for a structure or project.

(b) The graduate has demonstrated the output from the determinable model by changing parameters or details within the conceptual model. An example would be selecting different materials to examine the effect on component size.

6.1.5 Ability to select optimum system parameters and create physical models

(a) The graduate has demonstrated the ability to assemble a holistic solution to the problem or need from the outputs of the determinable models; for example the specification and drawing up of a construction scheme involving, say, geometrical layout as well as structural detailing.

(b) The graduate has demonstrated the ability to recognise and choose working methods or constructional techniques appropriate to the production of components of the real target system. Guidance may be necessary due to limited practical knowledge.

(c) The graduate has demonstrated the ability to recognise a range of possible solutions amongst those generated by the determinable model. For example, these might take into account factors such as ‘buildability’, practicality, fabrication, construction difficulties, safety considerations, availability of materials, aesthetics and other factors.

6.1.6 Ability to apply the results from physical models to create real target systems

(a) The graduate has demonstrated the ability to prepare a detailed specification of the real target system, for example by preparing documentation sufficient for tendering purposes of some aspects of a scheme.

(b) The graduate has demonstrated the ability to understand practical construction methods for some aspects of the real target system and prepare a method statement to indicate construction and functional viability, operating within relevant legislative guidance.

(c) The graduate has demonstrated the ability to produce a programme of construction or manufacture for the realisation of the real target system in an effective and efficient way. For example this might include Bar Charts and critical path programming. The optimisation of efficiency would not be expected.

(d) The graduate has demonstrated the ability to prepare estimates of the costs associated with producing the real target system.

6.1.7 Ability to critically review real target systems and personal performance

(a) The graduate has demonstrated the ability to make judgements about the suitability of conceptual models based on reviews of the performance of similar real target systems, possibly requiring help and guidance to compensate for experiential shortfalls.

(b) The graduate has demonstrated the ability to identify environmental and safety hazards associated with the constructional process or materials and suggest suitable techniques for reducing the risks of such hazards.

(c) The graduate has demonstrated the ability to identify environmental and safety hazards associated with the operation and maintenance of the real target system and suggest suitable techniques for managing these hazards. This might include the production of a risk assessment statement for a construction project, for example, an analysis of accident risk of a river lock system operation or vehicle collision with a bridge parapet. Some incompleteness would be expected.

(d) The graduate has demonstrated the ability to identify legal and statutory limitations and demands placed on the constructional process and on the operation of the real target system.

(e) The graduate has demonstrated the ability to appraise, review and select conceptual models in a team setting, for the promotion of an effective real target system. For example, the graduate would be expected to organise team meetings, set team targets and manage meetings.

6.2 Exemplar benchmarked abilities for IEng graduates in Civil Engineering – University of Portsmouth

The following list of Benchmarked 'Ability to…Statements' has been devised by members of the Department of Civil Engineering at the University of Portsmouth in the context of its BTech (non-honours) degree in Civil Engineering, accredited by the Joint Accreditation Panel (JAP). The course had been run for many years but was discontinued at the end of academic year 2000/01.

These statements have been devised by comparing and where necessary modifying 'Ability to…Statements' devised for degrees leading to CEng by the Universities of Bristol and Southampton in the context of their MEng Programmes.

Generally each statement is an extension of the corresponding generic 'Ability to…Statement' in the format:

> 'The graduate has demonstrated the ability to do X in the context of Y or its equivalent. (X is the body of the 'Ability to…Statement' and Y is a discipline-specific engineering system with a level of complexity, in terms of the required skill, knowledge and understanding, that is widely understood within the discipline.)'

Where appropriate the attainment-descriptor ability is replaced by awareness, knowledge or experience.

The benchmarked 'Ability to…Statements' are only intended to be examples of the expected capabilities of civil engineering IEng degree graduates at the threshold which might reasonably be expected by an informed practitioner in the civil engineering discipline. As such, lists of topics within civil engineering are presented as indicative of the level of attainment and not as exhaustive indications of syllabus content. Abilities that are developed through undergraduate project work are described in terms of a 'benchmark project' to avoid repetition.

In the following statements the level of complexity of the final year 'benchmark project' is presented for the design of a steel bridge with a span of about 100m carrying a canal over a 6-lane motorway.

BTech students worked in mixed teams with BEng(Hons)/MEng students at level 3.

6.2.2 Ability to transform existing systems into conceptual models

(a) The graduate has demonstrated experience in understanding, interpreting and clarifying client's true needs in the context of the design of civil engineering systems equivalent in complexity to the benchmark project.

(b) The graduate has demonstrated an ability to identify, classify and describe civil engineering systems such as the classification of statically-determinate and indeterminate structures, and hydraulic behaviour through problem-based learning and design exercises.

(c) The graduate has demonstrated an ability to define real target civil engineering systems in terms of objective functions, performance specifications and other constraints (ie define the problem) in the context of simple civil engineering systems such as concrete footings, steel portal frames and concrete frames through problem-based learning and design exercises.

(d) The graduate has demonstrated experience of taking account of risk assessment, and environmental impacts, in the setting of constraints (including legal, and health and safety issues) in the context of the design of a civil engineering system equivalent in complexity to the design of for example a water supply system for a medium-sized conurbation.

(e) The graduate has demonstrated ability in selection, review and experiment with existing civil engineering systems in order to obtain a database of knowledge and understanding that will contribute to the creation of specific real target civil engineering systems in the context, for example, of the influence of mix design on the strength and properties (including shrinkage and cracking) of concrete elements, and the role of shear strength in controlling behaviour and deformation of soils and experience in using the knowledge base from individual civil engineering subjects in the context of the design of civil engineering systems equivalent in complexity to the benchmark project.

(f) The graduate has demonstrated experience in resolution of difficulties created by imperfect and incomplete information in the context of the design of civil engineering systems equivalent in complexity to the benchmark project.

(g) The graduate has demonstrated ability in derivation of conceptual models of real target civil engineering systems, in the context of simple civil engineering systems through the interpretation of the brief; problem identification; initial concepts and has demonstrated experience in the context of the design of civil engineering systems equivalent in complexity to the benchmark project.

6.2.3 Ability to transform conceptual models into determinable models

(a) The graduate has demonstrated ability to construct determinable models over a range of complexity to suit a range of conceptual models in the context of the analysis of: structural elements and systems such as the plastic collapse of steel elements, and the ultimate load capacity of concrete slabs; geotechnical structures such as footings, retaining walls, piles, and slopes, and the flow of water in open channels with varying sections including hydraulic jumps.

(b) The graduate has demonstrated experience in the use of the underlying mathematical concepts and computing skills applying them to create determinable models: for example, solving differential equations to determine compression capacity of structure elements with proper understanding of the theoretical assumptions and boundary conditions.

(c) The graduate has demonstrated experience in the use of industry standard software tools and platforms to set up determinable models in the context of computer aided draughting (such as AUTOCAD), and the application of spreadsheet tools (for example Excel), numerical analysis (such as QSE, SLOPE, ReWARD) to the design and analysis of civil engineering systems through problem based learning and design exercises.

(d) The graduate has demonstrated experience in recognising the value of determinable models of different complexity and the limitations of their application in the context of the design of civil engineering systems equivalent in complexity to the benchmark project.

6.2.4 Ability to use determinable models to obtain system specifications in terms of parametric values

(a) The graduate has demonstrated the ability to work from data sheets and other sources and information such as Codes of Practice and manufacturers design literature to ensure that components and systems are used within the limits of their design specifications.

(b) The graduate has demonstrated experience in the use of industry standard software platforms and tools to solve determinable models in the context of the application of spreadsheet tools (for example, Excel), numerical analysis (such as QSE, SLOPE, ReWARD) to the design and analysis of civil engineering systems.

(c) The graduate has demonstrated the ability to set up and carry out routine tasks such as testing structural models in the laboratory, accurately logging and analysing the results.

(d) The graduate has demonstrated experience in engineering judgement of results and, if inadequate or invalid, improve knowledge database by further reference to existing systems.

6.2.5 Ability to select optimum specifications and create physical models

(a) The graduate has demonstrated experience in using client's brief and constraints to identify appropriate specifications in the context of the design of a civil engineering system equivalent in complexity to the benchmark project.

(b) The graduate has demonstrated experience in testing physical models and collating results such as for example the behaviour of steel struts, the deflection of pin jointed frames and the rotational stiffness of beams.

6.2.6 Ability to apply the results from physical models to create real target systems

(a) The graduate has demonstrated knowledge of the need to write sufficiently detailed specifications of real target civil engineering systems, including risk assessments and impact statements, in the context of the design of civil engineering systems such as the water supply system to a medium sized city.

(b) The graduate has demonstrated awareness of the need to select production methods and write method statements in the context of the design of civil engineering systems such as for example the construction activity of foundation piling for a project.

(c) The graduate has demonstrated awareness of the need to implement production and deliver products fit for purpose, in a timely and efficient manner, in the context of the design of civil engineering systems such as for example time and resource allocation for a design and management project.

(d) The graduate has demonstrated awareness of the need to operate within relevant legislative frameworks such as health and safety and environment in the context of the design of civil engineering systems such as the modification of construction method statements following a risk analysis of a construction project such as for example a sports stadium.

6.2.7 Ability to review critically real target systems and personal performance

(a) The graduate has demonstrated awareness of testing and evaluation of real systems in service against specification and client needs in the context of the design of civil engineering systems equivalent in complexity to the benchmark project.

(b) The graduate has demonstrated awareness of the need to recognise and make critical judgements about related environmental, social, ethical and professional issues in the context of the design of civil engineering systems equivalent in complexity to the benchmark project.

(c) The graduate has demonstrated awareness of the need to identify professional, technical and personal development requirements and undertake appropriate training and independent research through successful completion of relevant taught units, through engagement with activities of the Institution of Civil Engineers, and through the completion of a research project within a particular area of civil engineering.

6.3 Exemplar benchmarked abilities for IEng graduates in Mechanical Engineering – Sheffield Hallam University

The following statements are an attempt by academic staff from the School of Engineering at Sheffield Hallam University, to define the minimum level of skills, knowledge and understanding to be expected of a mechanical engineer, graduating from a course of study which has been accredited as providing the academic requirements for registration as an Incorporated Engineer.

The general format of the original EPC generic description of an engineer has been retained, with exemplars indicative of the minimum level of attainment introduced where applicable. The specific exemplars cited here form the basis for assignments, case-study work and projects currently in use on the final year of the IEng accredited honours degree course at Sheffield Hallam University. These exemplars are considered to reflect a level of complexity such that a third class graduate from an IEng accredited route should be capable of producing a workable solution, with only a limited amount of guidance and intervention from a more experienced engineer.

A graduate mechanical engineer, on completion of a course of study accredited for IEng, would be expected to possess:

6.3.2 The ability to transform existing systems into conceptual models

This would entail the application of engineering analysis and design concepts to arrive at a possible solution/s to a mechanical engineering problem. It would require the graduate to possess the ability to:

(a) Communicate with a client, who may be a non-technical person, to elicit and clarify the client's true needs, clearly and unambiguously.

(b) Identify, classify and describe the key physical parameters which define the operational requirements/characteristics of a component/product/system of a level of complexity equivalent to, for example:
- a simple two-speed gear box;
- a deck winch for a fishing trawler;
- a punch and die assembly to produce single punched holes of an irregular shape in sheet metal;
- a transmission system for a bull-block, wire drawing machine;
- a forging manipulator arm;
- a simple pump and pipeline for a water delivery system.

(c) Define the nature of a design problem of the type and complexity of those listed in 6.3.2 (b), in the form of a design specification expressed in terms of key physical/mechanical engineering parameters, for example, dimensions, resolved forces, stresses, stiffness, torque, creep, thermal/energy parameters, fluid flow, cost, ability to manufacture, etc.

(d) Take account of risk assessment and social and environmental impacts, in the setting of constraints. These may include legal constraints, health and safety issues, typical of that which would need to be considered in, for example, the design of:
- a customised wheel chair for a disabled person;
- an exposed rotating transmission system or forced draught fan assembly;
- a conveyor belt and drive system in a manufacturing plant.

(e) Draw on knowledge of nationally accepted design standards or existing/similar products/components/systems from a variety of sources, that will contribute to the creation of a design of products/systems of the type and level of complexity of the exemplars identified in 6.3.2 (b) and 6.3.2 (d).

(f) Recognise where information is incomplete or inadequate to complete the task and resolve such difficulties created by, for example:
- reasoned estimation of physical/mechanical parameters based on the analysis of similar products/components/systems;
- seeking the advice of more experienced/informed engineers.

(g) Produce engineering drawings consistent with BS 8888 and supporting descriptions of the conceptual solution to problems of the type and complexity identified above. These would be defined in terms of the important design parameters, such as dimensions, load-bearing capability, materials selection, etc, with due consideration of the method of manufacture and assembly, cost and commercial constraints. Such design would entail the proficient use of a modern CAD package, such as AutoCAD or Pro-Engineer, which might entail a level of proficiency illustrated by the following examples:
- detailed drawings of a welded steel fabrication for a pneumatic/hydraulic assembly, based on established standards and customer specification;
- a 3-D model and 2-D manufacturing drawings of a simple, single reduction winch to their personal design;
- produce and refine 3-D CAD drawings of, say, an innovative turbine blade based on a conceptual design and specifications/parameters defined by a more experienced (but possibly less CAD proficient) Chartered engineer or equivalent.

6.3.3 Ability to transform conceptual models into determinable models

The transformation of a conceptual design into a mathematical and/or computer model would require the graduate to possess the ability to:

(a) Select appropriate mathematical or computer based techniques and apply them to analyse conceptual designs covering a variety of situations ranging from the loading of a single component stressed member in a structure, mechanisms of moderate complexity, fluid flow problems and energy balances. Illustrative examples of appropriate complexity might include the analysis of :
- the stress and deflection in the structural elements of a pipe cutting machine;
- the load distribution within the components of a scissor lift mechanism;
- the effect of a sudden expansion in a pipe line;
- the air flow over a static aerofoil section.

(b) Use mathematics and computing skills to create quantitative analytical models by applying appropriate constitutive equations and specifying appropriate boundary conditions. Appropriate examples might include:
- the determination of the forces and stresses in the roof trusses of a large, moderately complex steel frame building, using the resolution of forces;
- the calculation of the overall dimensions and mass distribution of a flywheel to absorb a specified amount of energy fluctuation in a system.

(c) Use industry standard, finite element analysis software, such as ABAQUS, to set up model simulations in order to analyse, for example:
- the principal stresses and deflection in a simple two-dimensionally loaded beam or cantilever;
- two-dimensional plane strain in a tensioned rectangular plate containing holes;
- the stress distribution due to shrink fitting two thick cylinders of dissimilar materials.

(d) Recognise the value of such techniques at different levels of complexity up to the benchmark exemplar standard, but also appreciate the limitations of their application and in particular that the results from FEA techniques are only an approximation.

6.3.4 Ability to use determinable models to obtain system specifications in terms of parametric values

This would entail the use of mathematical and/or computer modelling techniques to obtain detailed predictions of the behaviour of the system being designed. It would require the graduate to possess the ability to:

(a) Use mathematics and computing skills to manipulate and solve model/simulations of the type and complexity identified in 6.3.3, using data sheets in an appropriate way to supplement solutions.

(b) Use industry standard software platforms and tools, such as ABAQUS, to solve models/simulations of engineering problems of the complexity defined in 6.3.3.

(c) Carry out a parametric sensitivity analysis to determine, for example, the effect of grid size employed or the conditions for solution convergence in the FEA of :
- a two-dimensionally loaded cantilever beam;
- a rectangular plate containing holes under simple tensile loading.

(d) Critically assess the results and, if inadequate or invalid, improve the knowledge data base by further reference to existing systems, possibly seeking the advice of more experienced engineers.

6.3.5 Ability to select optimum specifications and create physical models

This would entail the construction a prototype or physical model based on information from 6.3.2, 6.3.3 and 6.3.4 above, followed by the implementation of a programme of practical testing to evaluate its performance. It would require the graduate to possess the ability to:

(a) Identify those parameters essential to the functioning of the product/system, to be evaluated by physical modelling. Examples of appropriate complexity might include the evaluation of:
- the effect of wind speed on the power output from a small wind turbine generator relative to turbine blade geometry and the structural loading on its component parts;
- the rate of wear of the component parts of a roller-plate assembly of the type used in a simple sheet feeder device.

(b) Based on data obtained from computer/mathematical modelling construct a prototype or physical model, up to the complexity required by the exemplars defined in 6.3.5 (a), and conduct tests to evaluate performance.

(c) Collate and analyse the results from 6.3.5 (b) and feed these back into mathematical/ computer models in order to further refine and develop the design.

6.3.6 Ability to apply the results from physical models to create real target systems

The foregoing stages would culminate in the construction of the final component/ product/system, requiring the graduate to possess the ability to:

(a) Write a detailed specification of the product/system, including risk assessments and impact statements for any of the exemplars of complexity equivalent to those cited in 6.3.2 to 6.3.5 above.

(b) Select appropriate production methods and specify the production/processing route.

(c) Implement production and deliver products fit for purpose, in a timely and efficient manner.

(d) Operate within relevant legislative frameworks.

6.3.7 Ability to critically review real target systems and personal performance

The critical evaluation of the final component/product/system and the graduate's personal performance would require the graduate to possess the ability to:

(a) Test and evaluate the product/system in service against specification and client needs and retrospectively assess its suitability for purpose in relation to the foregoing analysis and design process. For example:
- waste disposal, recycling and re-use of consumer products;
- atmospheric emissions relating to fossil fuels.

(b) Recognise and make critical judgements about related environmental, social, ethical and professional issues in an evolving socio-economic climate. This might involve further development of the product/system to accommodate changing attitudes of society, and changes in legislation and standards, such as ISO 14000, with respect to environmental issues, for example:
- waste disposal, recycling and re-use of consumer products;
- atmospheric emissions relating to fossil fuels.

(c) Identify personal professional and technical development needs in order to maintain competency in a technologically evolving environment and undertake appropriate training and independent research.

6.4 Exemplar benchmark statements for graduate IEng Electrical and Electronic Engineers and Mechatronics Engineers – University of Glamorgan

The School of Electronics at the University of Glamorgan operates four IIE-accredited courses, the HND and BSc (Unclassified) in Electrical and Electronic Engineering and the HND and BSc (unclassified) in Mechatronics Engineering. The BSc awards were designed in as a result of recommendations made in the Engineering Council's SARTOR 1990 document. These awards were specifically designed to meet the requirements of an IEng - accredited graduate and are explicitly not a fallback award from honours degree.

The awards were revalidated in 1995 and modified to reflect current thinking at the time. The following generic exemplar benchmarks have been devised to reflect the ethos of the above IEng-accredited awards. The statements attempt to illustrate the minimum level of attainment expected of graduates studying for the BSc (unclassified) award.

We believe that the major differences between a BEng award leading to Chartered Engineer and the BSc award leading to Incorporated Engineer can be summed up by the following statement:

> 'The difference between a CEng and an IEng is that, the former makes policy, allocates priorities and manages resources at a senior level, whilst the latter implements policy in accordance with given priorities and manages resources at a junior level.'

We see the major differences in the A2 statements between the BEng and BSc as being in the taxonomy used reflecting the ethos described above. We have carefully examined the EPC 'Ability to…Statements' and feel that the existing A2 statement headings are appropriate for the IEng courses. We have included one modified A2 statement in our Mechatronics award but would not be concerned should the original A2 statement be used instead of the modified statement.

We also believe that the other defining feature of the two awards leading to CEng or IEng is the project. The School has defined a set of project attainment descriptors for each type of award, which are include below, to show the different ethos.

Project Level Descriptors

Unclassified Degree

(a) Demonstrate a critical understanding of well-established principles of the field and use them to analyse the problem and propose solutions.

(b) Demonstrate the ability to apply those principles outside the context in which they were taught.

(c) Demonstrate the ability to apply knowledge in novel ways or novel combinations to achieve solutions to problems, produce artefacts or meet specified needs.

(d) Gain new competencies (self directed learning).

(e) Choose critically the appropriate approach to solving the problem using their own initiatives.

(f) Avoid using methods outside of their domain of applicability

(g) Communicate the above to specialist and non-specialist audiences

(h) Carry out the above with some guidance from an academic supervisor

Honours Degree

(a) Demonstrate a critical and conceptual understanding and detailed knowledge of the principles of the subject, some of which are at the forefront of the field (for example, in recently published journals).

(b) Extend knowledge and understanding by self-study (eg of journals and advanced texts).

(c) Demonstrate the ability to apply knowledge in novel ways or novel combinations to achieve solutions to problems, produce artefacts or meet specified needs.

(d) Initiate (ie plan in concept and execution) projects involving relatively complex sequences of knowledge/skills. Evaluate alternative methods of achieving the desired outcomes and use appropriate experimental methods and tools during the execution.

(e) Argue critically and, where appropriate in the abstract, including evaluating the veracity of data or conclusions and using judgement where the data is incomplete or contradictory.

(f) Communicate the above to specialist and non-specialist audiences, including the sustaining of arguments in the face of questions and providing additional elaboration in response to questions.

(g) Carry out the above with the limited guidance from an academic supervisor

(6.4) Exemplar Benchmark Statements for IEng Graduates in Electrical and Electronic

Engineering – University of Glamorgan

6.4.2 Ability to transform existing systems into conceptual models (the extraction of key

operating parameters from a working system)

(a) The graduate has demonstrated the ability to identify and describe a wide range of electrical and electronic engineering systems, recognising the use of different design technologies (for example, analogue or digital), scale (for example, heavy power or microelectronic), and signal/power transmission methods (for example, cable, PCB, fibre etc).

(b) The graduate has demonstrated the ability to appreciate that different technologies may be used to achieve the same solution and that production volume, fabrication and testing costs will greatly influence the final choice: for example, the use of discrete components, embedded programmable systems, ASICs or other custom ICs.

(c) The graduate has demonstrated the ability to work safely, and be aware of work practice safety restrictions, such as ‘permit to work’ schemes and industrial codes of practice such as the IEE wiring regulations.

(d) The graduate has demonstrated the ability to work with data presented in a variety formats including graphical, schematic, net lists and databases. For example, the realisation of a PCB design using schematic capture information and EDIF files, or a planned maintenance schedule database.

(e) The graduate has demonstrated the ability to communicate both verbally and in writing to elicit the required data and thereby resolve difficulties caused by incomplete information: for example, component tolerances, temperature limits etc.

6.4.3 Ability to transform conceptual models into determinable models (the transformation of the key operating parameters into an algorithm)

(a) The graduate has demonstrated the ability to apply knowledge and understanding of well-established electrical and electronic engineering principles and methods to solve everyday problems: for example, the wiring of a building for light and power, the commissioning of electrical plant, or the use electrical instruments to test and fault-find simple electronic circuits.

(b) The graduate has demonstrated the ability to use industry standard software tools, such as CAD and circuit simulation packages to analyse the operation of simple electronic circuits and transform schematic designs into working production drawings: for example, using the schematic design of a simple analogue or digital circuit as the input to a simulation package, such as Proteus, verifying correct operation, and then converting the schematic design into the production requirements of PCB layout and drilling information.

(c) The graduate has demonstrated the ability to recognise the limitations of software tools and to always verify correct circuit operation using prototypes before committing to production.

6.4.4 Ability to use determinable models to obtain system specifications in terms of parametric values (customise the algorithm by inserting appropriate values and constraints and solving to obtain output parameters)

(a) The graduate has demonstrated the ability to work from data sheets and other sources of information to ensure electronic components and systems are used within the limits of their design specification.

(b) The graduate has demonstrated the ability to set up and carry out routine tasks, such as testing electrical/electronic circuits or following a planned maintenance schedule, and accurately logging the results.

6.4.5 Ability to select optimum specifications and create physical models (consider the output parameters and select the appropriate component/ manufacturing technology)

(a) The graduate has demonstrated the ability to be aware of the constraints that influence the final choice of circuit/system design: for example, weight and size restrictions may dictate the use of surface mount technology, or high-density component layout may necessitate forced cooling.

(b) The graduate has demonstrated the ability to accurately record data, predict possible outcomes and use this to take corrective action: for example, trend analysis of, say, the temperature of a wave solder bath on a PCB production line, or component values during ‘goods inwards’ inspection.

6.4.6 Ability to apply the results from physical models to create real target systems (apply the selected technology to obtain a physical realisation)

(a) The graduate has demonstrated the ability to write production procedures, taking due regard of any health and safety or other regulatory requirements or accepted working practices.

(b) The graduate has demonstrated the ability to implement production procedures and deliver goods fit-for-purpose, in a timely and efficient manner with a minimum of supervision.

(c) The graduate has demonstrated the ability to be aware of relevant legislative frameworks such as health and safety and EMC.

6.4.7 Ability to review critically real target systems and personal performance (maintain a watching brief and modify/ improve whenever possible)

(a) The graduate has demonstrated the ability to implement simple test and measurement procedures and to compare the results with expected outcomes. Examples would include the in-circuit testing of simple passive components, or the functional testing of simple analogue (frequency response) or digital circuits (truth table).

(b) The graduate has demonstrated the ability to appreciate that ethical and environmental considerations invariably influence engineering decision making.

(c) The graduate has demonstrated the ability to recognise the need for continual professional development in order to keep up to date with current thinking and stay abreast of technology changes.

6.5 Exemplar Benchmark statements for IEng Graduates in Mechatronics Engineering – University of Glamorgan

6.5.2 Ability to transform existing systems into conceptual models

(a) The graduate has demonstrated the ability to discuss and comprehend the requirements of an agreed specification for a mechatronic system equivalent in complexity to a PLC-controlled servomechanism.

(b) The graduate has demonstrated an ability to identify the function of a real mechatronic system and its component parts.

(c) The graduate has demonstrated an ability to contribute to the task assessment of a mechatronic system.

(d) The graduate has demonstrated the ability to write a risk assessment, taking into account social and environmental impacts (including legal and health, safety and welfare issues) in the assembly, dismantling, testing and commissioning of a mechatronic system.

(e) The graduate has demonstrated the ability to record operating data from a mechatronic system and to determine from this data, the replacements and adjustments necessary to maintain system operation within a prescribed specification.

(f) The graduate has demonstrated an ability to assess mechatronic system performance and to recommend possible improvements.

(g) The graduate has demonstrated the ability to identify and symbolise signal flow through the elements of a mechatronic system, representing the conditioning, shaping, actuation and conversion to which each signal is subjected.

6.5.3 Ability to transform conceptual models into determinable models

(a) The graduate has demonstrated the ability to select signal conditioning circuits for interfacing between mechatronic elements including sensors, analogue to digital and digital to analogue converters, PLCs, analogue and digital controllers, and actuators. The selection is made from manufacturers' catalogues and data-sheets.

(b) The graduate has demonstrated an ability to construct Laplace Transform and Z-transform first and second order models of mechanical, electrical, electronic and hydraulic systems, from first principles.

(c) The graduate has demonstrated the ability to construct a continuous-time and discrete-time models of a closed-loop mechatronic system, including non-linearities, using an appropriate computer package (eg MATLAB) to simulate the systems.

(d) The graduate has demonstrated an ability to recognise the limitations of the Determinable Models constructed.

6.5.4 Ability to use determinable models to obtain system specifications in terms of parametric values

(a) The graduate has demonstrated the ability to use appropriate computer software to ascertain the response of simulated mechatronic systems and elements. System responses are compared with normalised responses on data-sheets and design parameters obtained.

(b) The graduate has demonstrated an ability to use data sheets and test equipment to ascertain and adjust the design parameters of software models of mechatronic systems and elements.

(c) The graduate has demonstrated an ability to ascertain the time constants, damping and steady-state error of a simulated closed-loop mechatronic system and to determine its relative stability and sensitivity.

(d) The graduate has demonstrated an ability to use simulation systems to investigate and where necessary modify systems, to enhance performance.

6.5.5 Ability to implement given specifications and produce physical models (Modified)

(a) The graduate has demonstrated an ability to construct, test and calibrate a design for a mechatronic system, element, or signal path.

(b) The graduate has demonstrated an ability to implement studies on determinable models to obtain critical information, as directed.

(c) The graduate has demonstrated an ability to support performance testing of determinable models, as directed.

6.5.6 Ability to apply the results from physical models to produce real target systems

(a) The graduate has demonstrated an ability to follow detailed specifications of real target systems, and to heed risk assessments and impact statements.

(b) The graduate has demonstrated an ability to write a PLC program to control the sequence of operation of a mechatronic system to meet a given specification.

(c) The graduate has demonstrated an ability to operate within relevant legislative frameworks and considered all Health and Safety requirements.

6.5.7 Ability to critically review real target systems and personal performance

(a) The graduate has demonstrated an ability to test against specification and report on the performance of real systems in service, and on client needs.

(b) The graduate has demonstrated an ability to recognise and report on related environmental, social, ethical and professional issues.

(c) The graduate has demonstrated an ability to identify professional, technical and personal development needs and to seek appropriate training.

6.6 Exemplar Benchmarked Abilities for Incorporated Mechanical Engineering Graduates – Coventry University

The following list of Benchmarked 'Ability to…Statements' has been devised by members of the School of Engineering at Coventry University. Each statement is an extension of the corresponding generic 'Ability to...Statement' in the format:

'The graduate has demonstrated the ability to do X in the context of Y or its equivalent.

[X is the body of the 'Ability to…Statement' and Y is a discipline specific engineering system with a level of complexity, in terms of the required skill, knowledge and understanding that is widely understood within the discipline.]'

Where appropriate the attainment descriptor ability is replaced by awareness or knowledge. The benchmark statements are intended to be examples to those who need to know the minimum capability of an Incorporated Mechanical Engineering graduate. Various topics within mechanical engineering are presented as indicative of the level of attainment and are not exhaustive indications of syllabus content. Abilities that are developed through undergraduate project work are described in terms of 'benchmark projects' to avoid repetition.

In the following statements the level of complexity of the "benchmark projects" is that involved in a mechanical design, an experimental study or theoretical analysis typified by the following:

- The design of a mountain rescue stretcher;
- The construction and use of apparatus to study the slipping torque of an electric screwdriver;
- The use of computer based tools to analyse motor-car suspension movements and forces.

It should be noted that the words used to describe the output threshold standards are equally applicable to graduates from IEng and CEng courses. This is apparent when the specific examples of the 'Ability to…Statements' are compared.

By way of example, consider the ability to identify, classify and describe Engineering Systems [2.2]. The typical work for the IEng students was the reverse engineering of a Bosch electric hand drill. The tasks were well defined and the students were guided through the exercise. For a group of MEng students the corresponding first year exercise was to reverse engineer a Rover K series engine. The students started by setting their own objectives, proceeded with the task and were more in control of the learning process. Threshold technical competencies are thus broadly comparable; the difference between IEng and CEng graduates is in ability to take initiative and to lead.

6.6.2 Ability to transform existing systems into conceptual models

(a) The graduate has demonstrated ability in preceding a design study with a discussion with the client, from which a need definition is developed using a series of unambiguous statements. This will be in the context of the design of a mechanical engineering product or system equivalent in complexity to the benchmark projects.

(b) The graduate has demonstrated an ability to identify the inputs and outputs in a system, to classify internal and external forces and to describe the system characteristics in terms of the number of degrees of freedom and whether flow is laminar or turbulent. This will be in the context of the design or analysis of a mechanical engineering system equivalent in complexity to the benchmark projects. The gearbox of the Bosch drill is a typical example.

(c) The graduate has demonstrated an ability to develop a design specification for a real target mechanical engineering system in terms of objective functions and performance statements whilst avoiding unnecessary constraints on potential solutions and being mindful of existing approaches. This will be in the context of simple systems such as a four-bar linkage, or a shaft bearing on a water pump. The graduate has demonstrated ability in the context of the design of mechanical engineering systems equivalent in complexity to the benchmark projects.

(d) The graduate has demonstrated ability to write a risk assessment, taking account of social and environmental impacts in the setting of constraints (including legal, and health and safety issues), in the context of the design of a mechanical engineering system equivalent in complexity to the benchmark projects. The design of a mountain rescue stretcher is a typical example.

(e) The graduate has demonstrated ability in selection, review and experiments with existing mechanical engineering systems in order to obtain a database of knowledge and understanding that will contribute to the creation of specific real target mechanical engineering systems. This will be in the context of the influence of material choice on the stress, stiffness and creep behaviour of polymeric elements used in place of metals, or the choice of machine components such as shafts, bearings and gears. Ability has been demonstrated in using the knowledge base from individual mechanical engineering subjects and associated technologies in the context of the design of mechanical engineering systems equivalent in complexity to the benchmark projects. This ability is typically acquired through laboratory activities and reverse engineering.

(f) The graduate has demonstrated ability to resolve difficulties created by imperfect and incomplete information by recognising when data is incomplete and providing additional information based on knowledge of the order of magnitude of the characteristics of common components. Design, make and test exercises (involving, for example, a simple bridge structure or spring powered model vehicle) provide early opportunity. Substantive design tasks such as the mountain rescue stretcher add realistic context.

(g) The graduate has demonstrated ability in derivation of conceptual models of real target mechanical engineering systems, including lumped parameter and distributed systems, identifying the key parameters in the context of simple mechanical engineering elements such as beam systems, mechanisms and moving bodies of constant and variable mass. Ability has been demonstrated in the context of the design of mechanical engineering systems equivalent in complexity to the benchmark projects.

6.6.3 Ability to transform conceptual models into determinable models

(a) The graduate has demonstrated ability to construct determinable models over a range of complexity to suit a range of conceptual models in the context of :

- applying Newton's laws of motion and energy balances within systems such as a spring-mass-damper, and a flywheel;
- the analysis of stressed elements and systems such as a crane hook or cranked lever;

- the deflection of beam systems such as a geared shaft;
- the flow of water in pipes and the losses arising therefrom.

(b) The graduate has demonstrated ability to use mathematics and computing skills to create determinable models by deriving appropriate constitutive equations and specifying appropriate boundary conditions in the context of :

- applying Newton's laws of motion and energy balances within systems such as a spring-mass-damper, and a flywheel;
- the analysis of: stressed elements and systems such as a crane hook or cranked lever;
- the deflection of beam systems such as a geared shaft;
- the flow of water in pipes and the losses arising therefrom.

(c) The graduate has demonstrated ability to use industry standard software tools and platforms to set up determinable models using a CAD system (such as AUTOCAD) to create geometrical models of components and assemblies, and using a numerical analysis modeller (such as MatLab) to investigate natural modes of vibration using Eigenvalue analysis. This has been demonstrated in the context of the design and analysis of mechanical engineering systems equivalent in complexity to the benchmark projects.

(d) The graduate has demonstrated experience in recognising the value of determinable models of different complexity and the limitations of their application in the context of the design of mechanical engineering systems equivalent in complexity to the benchmark project, and has shown ability to demonstrate how one conceptual model (such as a beam or shaft) can be described by a range of determinable models of differing complexity. The motor car suspension analysis provides a typical medium for this.

6.6.4 Ability to use determinable models to obtain system specifications in terms of parametric values

(a) The graduate has demonstrated ability to use mathematics and computing skills to manipulate and solve determinable models and to use data sheets in an appropriate way to supplement solutions in the context of :

- applying Newton's laws of motion and energy balances within systems such as a spring-mass-damper, and a flywheel;
- the analysis of stressed elements and systems such as a crane hook or cranked lever;
- the deflection of beam systems such as a geared shaft;
- the flow of water in pipes and the losses arising therefrom.

(b) The graduate has demonstrated experience in the use of industry standard software platforms and tools to solve determinable models using a CAD system (such as AUTOCAD) to create geometrical models of components and assemblies, and using a numerical analysis modeller (such as MatLab) to investigate natural modes of vibration using Eigenvalue analysis. This has been demonstrated in the context of the design and analysis of mechanical engineering systems equivalent in complexity to the benchmark projects.

(c) The graduate has demonstrated ability to carry out a parametric sensitivity analysis (including, where appropriate, sensitivity in terms of performance and cost) in the context of:
- the analysis of stressed elements and systems such as a crane hook or cranked lever;
- the deflection of beam systems such as a geared shaft;
- the flow of water in pipes and the losses arising therefrom.

(d) The graduate has demonstrated experience in the critical assessment of results and of, if inadequate or invalid, improving the knowledge database by further reference to existing systems, and/or improving the performance of determinable models in the context of the design of mechanical engineering systems equivalent in complexity to the benchmark projects. This could take the form of, for example, revision of the type and size of a finite element mesh.

6.6.5. Ability to select optimum specifications and create physical models

(a) The graduate has demonstrated experience in using objective functions and constraints to identify optimum specifications in the context of the design of a mechanical engineering system equivalent in complexity to a motor cycle gearbox car suspension system and its low and high frequency response and handling.

(b) The graduate has demonstrated experience in planning physical modelling studies, based on determinable modelling, in order to produce critical information, in the context of the development of model tests to support the design of systems such as a rocker arm of a mechanism, or the testing of a non-contacting dimension measuring system. This could, for example, concern the location of strain gauges.

(c) The graduate has demonstrated experience in testing and collating results, feeding these back into determinable models, in the context of the development of model tests to support the design of systems such as a rocker arm of a mechanism, or the testing of a non-contacting dimension measuring system.

6.6.6 Ability to apply the results from physical models to create real target systems

(a) The graduate has demonstrated knowledge of the need to write sufficiently detailed specifications of a mechanical engineering system controlled or operated during the course (such as a simple machine tool pedal box movement/adjustment for driver comfort) including risk assessments and impact statements.

(b) The graduate has demonstrated awareness of the range of production methods available in industry, and the need to write method statements for the production of a moderately complex component such as a vehicle gearbox casing.

(c) The graduate has demonstrated knowledge of the need to implement production and deliver products fit for purpose, in a timely and efficient manner, by drawing up a detailed production plan for a moderately complex piece of equipment (such as a domestic appliance), demonstrating the balance of resource input to overall production time.

(d) The graduate has demonstrated awareness of the need to operate within all the relevant legislative frameworks in the context of the design of mechanical engineering systems equivalent in complexity to the benchmark projects.

6.6.7 Ability to review critically real target systems and personal performance

(a) The graduate has demonstrated awareness of testing and evaluation of real systems in service against specification and client needs and satisfaction level in the context of the design of mechanical engineering systems equivalent in complexity to the benchmark projects, and experience in the context of the design, construction and testing of a system such as a small electric vehicle.

(b) The graduate has demonstrated awareness of the need to recognise and make critical judgements about related environmental, social, ethical and professional issues in the context of the design of mechanical engineering systems equivalent in complexity to the benchmark projects, and experience of selecting a compromise solution and checking whether, with the value of hindsight, this compromise could have been improved.

(c) The graduate has demonstrated awareness of the need to identify professional, technical and personal development requirements and to undertake appropriate training and independent research through successful completion of relevant taught units, through engagement with activities of a professional body such as the Institution of Mechanical Engineers for CEng, and through the completion of a research project within a particular area of mechanical engineering.

7 References

1 EPC (2000) The EPC Engineering Graduate Output Standard – Interim Report of the EPC Output Standards Project, EPC Occasional paper Number 10, Engineering Professors Council

2 Engineering Council (1997) Standards and Routes to Registration – SARTOR 3rd Edition, Engineering Council

3 OSCEng (1999) Engineering Occupational Standards for Higher Levels – Version 2.0, Occupational Standards Council for Engineering

4 IIE (1998) Degree Programmes for Incorporated Engineers. The Institution of Incorporated Engineers

5 Engineering Council (2000) Making the best of valuable talent, Report of the Hawley Group, Engineering Council

6 QCA (2000) Key Skills Units Levels 1-3, Qualifications and Curriculum Authority

7 QCA (2000) Key Skills Units Levels 4-5, Qualifications and Curriculum Authority

Annex A

Working Group Membership and Acknowledgement

The Working Group met five times between 20 April 2001 and 18 December 2001 and wishes to thank the Royal Academy of Engineering for its generous support of facilities for group meetings during this time. Thanks are also due to Tim Feest, Director of OSCEng, for help with editing and formatting of the report for printing.

The Working Group comprised :

Professor David Woollons	University of Exeter (Chair after 20 April 2001)
Professor Brian Lee	University of Portsmouth (Chair to 20 April 2001)
Ian Cross	University of Portsmouth
Dr. Robin Acheson	Sheffield Hallam University
Professor Tom Ruxton	Staffordshire University
Dr Peter White	Coventry University
Dr Mike H Price	University of Glamorgan
Professor Roger Hawkins	Nottingham Trent University
Rev Stuart Poole	IIE
Tim Whiteley	EPC Project Officer

Annex B

Definitions

The 'Ability to…Statements' provide a language for describing a reasonable expectation of graduate attributes. However in the interests of clarity and efficiency of communication, it has been necessary to attribute very specific meanings to some words which have a wider range of meanings in common usage. These words are italicised when used in this restricted and particular sense and are defined below.

Standard	A definition of a reasonable and agreed level of attainment, which may be expressed as a collection of expected abilities. (For example, the EPC Engineering Degree Output Standard).
Engineering Degree Output Standard	A statement or description of the abilities recognised by the award of an engineering degree. The EPC Standard is in the form of a framework or template which facilitates this description for all engineering disciplines.
Threshold	The minimum level at which the demonstration of a set of expected abilities can be recognised by the award of an engineering degree or other qualification.
Benchmark	A level descriptor. A generic format for a benchmark statement is as follows. The graduate has demonstrated the ability to do X in the context of Y or its equivalent. [Y is a discipline specific engineering system with a level of complexity, in terms of the required skill, knowledge and understanding, that is widely understood within the discipline.] Benchmarks do not explicitly define a level, or scope, but illustrate it or imply it by example. (Examples of benchmarks are given in Section 2.)
Engineering	The distinguishing feature of Engineering, as distinct from science and the arts, is the exercise of imagination to create and bring to reality products, artefacts, techniques or services based on scientific principles, knowledge of materials, and the art of synthesis. An Engineer is one who practises all or part of this profession. The art of engineering is to translate a proposed engineering system into one or more appropriate conceptual models, to use these models to derive and apply the parameters that enable the production of a real target system, and then create that system. It is a process of deconstructing experience for the purpose of beneficial reconstruction.
Engineering Systems	A component or assembly of components, created by the application of engineering, which delivers an output by transforming an input. (For example: a bridge, an aeroplane, a power station, an engine, a mobile phone and so on, or the components of any of these; a technique or procedure such as an acceptance-test procedure or a maintenance schedule for hospital diesel power generating plant.)
Real Target System	An Engineering System which is the physical realisation of the solution to an engineering problem.
Systems Constraints	Limitations on an engineering system imposed by client needs, as well as physical, environmental, ethical and social issues. (For example, vehicle seating capacity, noise limits, location.)
Objective Function	A statement which provides the means of evaluating the objective of the real target system in order to determine the key system parameters that will give the optimum performance of the system. (For example, a cost/benefit function)

Impact Statement	A description of the benefits and costs to the social and physical environment that will flow from the introduction of the real target system. (For example, a risk assessment of the construction of a chemical processing plant or an airport.)
Conceptual Model	A graphical, diagrammatic, symbolic or otherwise mentally apprehendable representation of an engineering system illustrating the relationship between key parameters in a form that may be transformed into a determinable model. (For example, the model used in a process diagram, a circuit diagram, a pipe network, a structural frame, a magnetic field pattern)
Determinable Model	A mathematical, computer/numerical, or logical representation of a conceptual model which enables the key system parameters to be firmly decided or definitely ascertained (For example, a finite element computer model, a set of algebraic equations.)
Physical Model	A physical representation of all or part of a real target system capable of being tested practically to determine or verify key system parameters. A prototype of the real target system. (For example, a wind tunnel test, a materials test, a field trial.)
Key System Parameters	Quantities that define an engineering system and its performance. (For example, lead dimensions, flow capacities, power requirements, material strengths.)
Specification	A description of an engineering system which is sufficiently detailed to enable it to be produced.
Know-how	Problem-solving capability based on experience rather than on conceptual learning

Annex C

A Comparison of Exemplar Benchmark Statements for Graduate CEng/IEng Mechanical Engineers

The following statements attempt to illustrate the differences between the minimum level of skills, knowledge and understanding to be expected of a mechanical engineer, graduating from a CEng accredited BEng (Hons) degree course, compared with one from an IEng accredited degree route.

It is intended that this document, essentially defining the minimum output standard of a 'CEng graduate', should be read alongside that previously prepared by staff from the School of Engineering at Sheffield Hallam University, defining the exemplar benchmark statements for an 'IEng graduate'.

There is much that is common between the two sets of descriptors. The principal differences for the 'CEng graduate' and additional comments are highlighted here by the use of *italics*. The modifications made, attempt to reflect the generally higher level of mathematical and computing skills expected of a 'CEng graduate' and the ability to tackle more demanding engineering problems, with more evident flair and originality in their solution.

The general format of the original EPC generic description of an engineer has been retained, with exemplars indicative of the minimum level of attainment introduced where applicable. The specific exemplars cited here, form the basis for assignments, case-study work and projects currently in use on the final year of the *CEng accredited BEng (Hons) degree course* at Sheffield Hallam University. These exemplars are considered to reflect a level of complexity, such that *a lower-second class* graduate should be capable of producing a workable solution, *essentially by their own efforts alone*.

A graduate mechanical engineer on completion of a course of study accredited for CEng, would be expected to possess:

C2 The ability to transform existing systems into conceptual models

This would entail the application of engineering analysis and design concepts to arrive at a possible solution/s to a mechanical engineering problem. It would require the graduate to possess the ability to:

(a) Communicate with a client, who may be a non-technical person, to elicit and clarify the client's true needs, clearly and unambiguously. [*No difference from IEng*]

(b) Identify, classify and describe the key physical parameters which define the operational requirements/characteristics of a component/product/system of a level of complexity equivalent to, for example:

- *a multiple, variable -speed gear box;*
- *a press die and punch assembly to form an irregular shaped deep drawn component;*
- *a transmission system for an automatic wire drawing machine;*
- *a robotic assembly cell;*
- *a gas fired heat exchanger system;*
- *an automatic beach cleaning and debris recovery machine.*

(c) Define the nature of a design problem of the type and complexity of those listed in C2 (b) in the form of a design specification expressed in terms of key physical/mechanical engineering parameters, for example, dimensions, resolved forces, stresses, stiffness, torque, creep, thermal/energy parameters, fluid flow, cost, ability to manufacture, etc. [*No difference from IEng*]

(d) Take account of risk assessment and social and environmental impacts, in the setting of constraints. These may include legal constraints, health and safety issues, typical of that which would need to be considered in, for example, the design of:
- *a page-turning machine for the manually disabled, intended for mass production;*
- *an automatic paper cutting/slitting machine;*
- *a machine for the disposal of waste canned products from a food processing line.*

(e) Draw on knowledge of nationally accepted design standards or existing/similar products/components/systems from a variety of sources, *where appropriate seeking to improve existing designs, or where none exist devising innovative solutions*, that will contribute to the creation of a design of products/systems of the type and level of complexity of the exemplars identified in C2 (b) and C2 (d).

(f) Recognise where information is incomplete or inadequate to complete the task and resolve such difficulties created by, for example:
- *the application of mathematical or computational modelling of physico-chemical parameters*;
- reasoned estimation of physical/mechanical parameters based on the analysis of similar products/components/systems.

(g) Produce engineering drawings consistent with B.S.8888 and supporting descriptions of the conceptual solution to problems of the type and complexity identified above. These would be defined in terms of the important design parameters, such as dimensions, load-bearing capability, materials selection, etc, with due consideration of the method of manufacture and assembly, cost and commercial constraints. Such design would entail the proficient use of a modern CAD package, such as AutoCAD or Pro-Engineer, which might entail a level of proficiency illustrated by the following examples:
- detailed drawings of a welded steel fabrication for a pneumatic/hydraulic assembly, based on established standards and customer specification;
- a 3-D model and 2-D manufacturing drawings of a simple, single reduction winch to their personal design.

[*Practical CAD skills might reasonably be expected to be inferior to those of an IEng graduate – note the omitted final exemplar from the IEng benchmark statements.*]

C3 Ability to transform conceptual models into determinable models

The transformation of a conceptual design into a mathematical and/or computer model would require the graduate to possess the ability to:

(a) Select appropriate mathematical or computer based techniques, *modifying and combining them as appropriate to obtain a good model of the system* and apply them to analyse conceptual designs covering a variety of situations ranging from the loading of a single component stressed member in a structure, mechanisms of moderate complexity, fluid flow problems and energy balances. Illustrative examples of appropriate complexity might include the analysis of :
- *the load distribution within the components of a swing arm crane;*

- *the analysis of the mixing of two dissimilar fluid streams within a pipeline or hydraulic manifold;*
- *the air flow through an axial fan.*

(b) *Demonstrate a high level of* mathematical and computing skills to create rigorous quantitative analytical models by applying appropriate constitutive equations and specifying appropriate boundary conditions. Appropriate examples might include:
- *the determination of the forces and stresses in a counter balanced flood gate;*
- *calculation of the internal forces developed in a flywheel during acceleration, applying fundamental principles to calculate the critical stresses and modify the design dimensions to satisfy structural integrity criteria.*

(c) Use industry standard, finite element analysis software, such as ABAQUS, to set up model simulations in order to analyse, for example:
- *the principal and Hertzian stresses and deflections in a three-dimensionally loaded cantilever with interconnecting beams;*
- *the three-dimensional stress distribution in a pressurised valve body;*
- *the stresses developed in a complex structure under coupled mechanical and thermal loading.*

(d) Recognise the value of such techniques at different levels of complexity up to the benchmark exemplar standard, but also appreciate *the effect of mesh size, element type, method of solution, etc on FEA analysis and be able to optimise results to achieve a convergent solution to the problem at minimum cost and effort*.

C4 Ability to use determinable models to obtain system specifications in terms of parametric values

This would entail the use of mathematical and/or computer modelling techniques to obtain detailed predictions of the behaviour of the system being designed. It would require the graduate to possess the ability to:

(a) Use mathematics and computing skills to manipulate and solve model/simulations of the type and complexity identified in C3 above, using data sheets in an appropriate way to supplement solutions.[*Wording as for IEng but with a more advanced mathematical/computational expectation implied by the exemplars.*]

(b) Use industry standard software platforms and tools, such as ABAQUS, to solve models/simulations of engineering problems of the complexity defined in C3.[*Wording as for IEng but with a more advanced mathematical/computational expectation implied by the exemplars.*]

(c) Carry out a parametric sensitivity analysis to determine, for example, the effect of grid size employed or the conditions for solution convergence in the FEA of :
- *a three-dimensionally loaded cantilever beam structure;*
- *a stressed component containing holes under complex loading.*

(d) Critically assess the results and, if inadequate or invalid, improve the knowledge data base by *further development of the system, possibly involving innovative approaches to the problem*.

C5 Ability to select optimum specifications and create physical models

This would entail the construction of a prototype or physical model based on information from C2, C3, C4 above, followed by the implementation of a programme of practical testing to evaluate its performance. It would require the graduate to possess the ability to:

(a) Identify those parameters essential to the functioning of the product/system, to be evaluated by physical modelling. Examples of appropriate complexity might include the evaluation of:
- *different types of lubrication system for a gearbox;*
- *the rate of wear and reliability of bearings and gears in a mechanical system.*

(b) Based on data obtained from computer/mathematical modelling construct [*] a prototype or physical model, up to the complexity required by the exemplars defined in C5 (a), and conduct tests to evaluate performance.
[* *Possibly 'supervise' construction, as practical skills may be inferior to those of an IEng.*]

(c) Collate and analyse the results from C5 (b) and feed these back into mathematical/computer models in order to further refine and develop the design. [*No difference from IEng.*]

C6 Ability to apply the results from physical models to create real target systems

The foregoing stages would culminate in the construction of the final component/ product/system, requiring the graduate to possess the ability to:

(a) Write a detailed specification of the product/system, including risk assessments and impact statements for any of the exemplars of complexity equivalent to those cited in C2-C5 above. [*No difference from IEng.*]

(b) Select appropriate production methods, *modifying and developing standard techniques where necessary* and specify the production/processing route.

(c) Implement production and deliver products fit for purpose, in a timely and efficient manner. [*No difference from IEng.*]

(d) Operate within relevant legislative frameworks. [*No difference from IEng.*]

C7 Ability to critically review real target systems and personal performance

The critical evaluation of the final component/product/system and the graduate's personal performance would require the graduate to possess the ability to:

(a) Test and evaluate the product/system in service against specification and client needs and retrospectively assess its suitability for purpose in relation to the foregoing analysis and design process, *and with respect to the possessive organisations' wider business and strategic objectives.*

(b) Recognise and make critical judgements about related environmental, social, ethical and professional issues in an evolving socio-economic climate. This might involve further development of the product/system to accommodate changing attitudes of society, legislation and standards, such as ISO14000, with respect to environmental issues, for example:

- waste disposal, recycling and re-use of consumer products;
- atmospheric emissions relating to fossil fuels.[*No difference from IEng.*]

(c) Identify personal professional and technical development needs in order to maintain competency in a technologically evolving environment and undertake appropriate training and independent research. [*No difference from IEng.*]

Report of the Professional Bodies' Working Group

The EPC Engineering Graduate Output Standard

Output standards and professional body accreditation

January 2002

The Engineering Professors Council

Published by
The Engineering Professors Council
Secretariat: c/o Institution of Mechanical Engineers
1 Birdcage Walk
London SW1H 9JJ
England

Printed in England by
Training Publications Ltd
Watford

Acknowledgement
Thanks are due to Tim Feest, Director of OSCEng, for help with editing and formatting of the report for printing.

Contents

Executive Summary

The framework of the Engineering Professors' Council (EPC) Engineering Graduate Output Standard takes the form of 26 'Ability to…Statements' that are expressed in generic non-discipline-specific terms and are based on the procedures carried out by an engineer in solving an engineering problem and delivering a solution.

Following publication of the Output Standard, the EPC commissioned five linked sub-projects. One of these dealt with the relationship of the Output Standard to the accreditation of engineering programmes by Engineering Professional Bodies on behalf of the Engineering Council. This report outlines the main areas discussed by the Professional Bodies Working Group (PBWG), the outcomes from these discussions, and recommendations. The membership of the PBWG represented eight Professional Bodies, and all of the other Professional Bodies licensed by the Engineering Council to accredit programmes were engaged as corresponding members.

Accreditation is the process by which an Engineering Professional Body assesses whether or not an engineering academic programme meets the requirements for initial registration of Engineers and Technicians in the Engineering Council's Register. This process is carried out in accordance with the guidance set down in the Engineering Council's policy document Standards and Routes to Registration, third edition (SARTOR 3). The first task of the Working Group was to review the practice of accreditation in the UK. It appears that all of the Professional Bodies represented on the PBWG adopt the same approach to accreditation, which is based on a careful assessment of both input and output measures by a peer review process. In general there are transparent codified criteria for the input measures. However decisions on whether or not graduates meet required output standards are based largely on the principle of connoisseurship. Most Professional Engineering Bodies do not use explicit exemplar benchmarks and do not attempt to compare the actual output being achieved against benchmarked standards. The PBWG believes that the use of benchmarks would allow decisions to be made in a much more explicit manner. The PBWG is of the opinion that on the whole the accreditation process was robust, but all agreed that the assessment of graduate output could be improved by the use of a standard such as the EPC Output Standard.

An attempt was made by the PBWG to map current accreditation practice on to the EPC Output Standard. Whilst the comparison showed a close correlation with the requirements of SARTOR 3, difficulties were experienced in devising benchmark statements which suited the wide range of programmes that Professional Bodies are invited to accredit. It was thought that an alternative approach would be to express a standard in terms of the complexity and open-ended nature of the tasks that graduates were expected to undertake, and that benchmarking a portfolio of exemplar tasks in these terms might be worth exploring.

The PBWG reviewed the accreditation processes of non-UK professional bodies and the role of Output Standards of other relevant UK professions. EU and American professional-body activity was included, and the UK professions of Medicine, Nursing, Law and Accountancy were covered. It is observed that professional bodies in the UK are attempting to assess the ability and capability of graduates through a greater focus being placed on the assessment of output.

The PBWG also took into account the Academic Standards produced by the Quality Assurance Agency (QAA) for both Engineering and Computing together with the report from the Joint EPC/QAA Compatibility Working Group which establishes the compatibility of the QAA Academic Standard – Engineering and the EPC Output Standard. This report concludes that the

QAA and EPC standards do not contradict each other but say very similar things, although in different formats. The report observes that opportunities will arise, in the not too distant future, for the principal stakeholders to determine whether the standards, including SARTOR 3, should be co-ordinated in some formal manner, or whether the retention of these different, but compatible perspectives for characterising what is expected of a graduate engineer provides opportunity and flexibility. The PBWG agrees that in any review of output standards all three documents should be considered but takes the view that, in the long term, harmonisation of the three approaches to output standards would in fact be very helpful to the accreditation process.

The PBWG observes that whilst the current approaches to academic programme accreditation are robust, there is room for improvement particularly in the assessment of graduate output. This improvement could be achieved through the acceptance of the following five recommendations:

1 The Engineering Council is urged to instigate a dialogue between itself, QAA, EPC and the Professional Engineering Bodies with a view to harmonising the three approaches to output standards so as to allow accreditation committees to make sound judgements using output criteria.

[**ACTION:** Engineering Council]

2 Professional Engineering Bodies are encouraged to move away from a concentration on the assessment of input to a more explicit use of agreed output criteria where appropriate and possible.

[**ACTION:** Professional Bodies]

3 Professional Engineering Bodies are urged to work on a mapping exercise to produce appropriate exemplar benchmarks and/or attributes to support the accreditation process in the assessment of graduate output.

[**ACTION:** Professional Bodies]

4 The Professional Engineering Bodies should work together through DABCE and JAB in order to harmonise the various accreditation processes used. This is of particular importance as the shift towards the assessment of graduate output occurs.

[**ACTION:** DABCE and JAB]

5 The EPC should monitor the progress on the four recommendations and report progress to its annual Congress in 2003.

[**ACTION:** EPC]

1 Background

In December 2000 the Engineering Professors' Council (EPC) published Occasional Paper Number 10 entitled 'The EPC Engineering Graduate Output Standard' [1]. This paper was the outcome of Phases 1 & 2 of the EPC Output Standard Project and defined a methodology for describing engineering graduate output standards. The framework established takes the form of 26 'Ability to…statements' that are expressed in generic non-discipline-specific terms and are based on the procedures carried out by an engineer in solving an engineering problem and delivering a solution.

In early 2001 EPC approved Phase 3 of the project. Phase 3 comprises five linked sub-projects with one of these sub-projects dealing with the relationship of the EPC Standard to the accreditation of courses on behalf of the Engineering Council by the Engineering Professional Bodies, see Annex 3. An accredited academic programme meets the requirements for initial registration of Engineers and Technicians in the Engineering Council's Register.

This report outlines the main areas discussed by the Professional Bodies Working Group (PBWG), the outcomes from these discussions, and recommendations. The overall aim is to encourage the peer review of benchmarks by the Professional Bodies in relation to the EPC Engineering Output Standard and to explore the benefits to those bodies of a single standard applicable across all engineering disciplines.

As the work of the PBWG was progressing the report, in its draft form, was read by a number individuals and groups from outside the membership of the PBWG but who had a professional interest in accreditation and the assessment of output. Quotes from two of these individuals, Professor Jim McQuaid and Professor Ernest Shannon, have been included in the body of the report as their contributions were considered to add significantly to the discussions and focus of the Working Group.

Professor Jim McQuaid is a Fellow of the Royal Academy of Engineering. He is currently a Royal Academy of Engineering visiting professor at the University of Ulster in Engineering Design and Sustainable Development. Until recently he was Director of Science and Technology at the Health and Safety Executive, London.

Professor Ernest Shannon is a Fellow and Vice President of the Royal Academy of Engineering, a past President of the IMechE and a past president of the Institution of Gas Engineers. He is an Executive Board Member of FEANI and is the FEANI representative on ESOPE.

Appendix 1 presents the rationale and terms of reference for the PBWG and Appendix 2 gives a list of working group members. In total 6 meetings were held.

2 Academic Programme Input and Output Measures

Throughout this report the terms 'input' and 'output' are extensively used. For the purposes of this report input refers to such things as the student entry qualification profile, the curriculum, detailed syllabi and stated learning outcomes, the learning resource base used in the delivery of an academic programme, the quality of the staffing base and their research, industrial involvement and industrial consultancy activities.

Similarly output refers to the ability and capability of the students who graduate from an academic programme.

As such, input can be assessed from the documents provided by Universities to the accreditation bodies for accreditation purposes supplemented by a panel visit, whereas output is much more difficult to assess. If output is to be assessed against a standard then achievements need to be compared with exemplar benchmarks, established in the standard, to determine the level of attainment. 'Learning Outcomes' are now used by many universities and Professional Bodies to assess what a graduate is expected to be able to do having studied a particular module or the complete academic programme. After much discussion the PBWG agreed that the identification of learning outcomes should be considered to be an input as these are specified by academic programme planners at the design stage. They do however, offer a language for expressing output achievements of students and hence student achievement can be judged against them.

> "The distinction I would draw is that an output can be directly measured ie solving linear differential equations – a prescriptive structure – whereas an outcome has to draw on collateral evidence of fulfilment ie an ability to apply knowledge of mathematics – a goal setting structure – with solving equations as one of many possible exemplar tasks."
> *Professor Jim McQuaid*

3 Review of Accreditation Practice in the UK

3.1 Overview of SARTOR 3 and the role of Professional Engineering Bodies in the Accreditation Process

The Engineering Council's policy document Standards and Routes to Registration, third edition (SARTOR 3) [2] sets out the criteria which all engineering degree courses must meet to gain accreditation. An academic programme will be accredited by one or more of the Professional Engineering Bodies, acting as agents of the Engineering Council, provided that the academic programme is deemed to have met the criteria identified in SARTOR 3 and is therefore considered to be 'fit for purpose'. Accreditation then, features an assessment process, followed by a decision about fitness for purpose.

The criteria established in SARTOR 3 relate to both inputs and outputs. In the former category, much of the attention has focused on the cohort admissions standards requirements which courses must meet. However there are other important input-related criteria which concern course content and structure (such as the need for MEng programmes to include a group project) and the need to set learning in the context of engineering applications.

Of more interest in the context of the work of the PBWG are the outcome statements which SARTOR 3 sets out for accredited degrees. These cover the knowledge, understanding, awareness and abilities which graduates from different types of degree courses should achieve. They are derived from the competencies which SARTOR 3 ascribes to Chartered and Incorporated Engineers and which candidates for registration must demonstrate at professional review. These competence statements are set out in SARTOR 3 Part 2, Sections 2.1.1 and 2.2.2, and the accreditation criteria are set out in Sections 4.1.1 and 4.1.2. Professional Engineering Bodies accredit courses in accordance with these generic criteria, which they have contextualised to their individual disciplines.

Professional Engineering Bodies are licensed by the Engineering Council to accredit academic programmes at Chartered Engineer or Incorporated Engineer level. Appendix 3 gives a list of licensed Professional Engineering Bodies. All members of the Working Group, who represented eight Professional Engineering Bodies, were asked to explain the accreditation procedures used by their individual Professional Bodies and to identify what they consider to be good practice. In particular they were also asked to explain if and how they assessed graduate output and the reasons for refusing to accredit. To enable informed discussion to take place all the Professional Bodies provided the Working Group with copies of their full range of accreditation documentation including copies of submission documents, check lists used by visiting teams and copies of visit report pro-forma used to present the outcomes of accreditation visits. They also outlined their disclosure policy. What follows is a summary of these discussions.

3.2 Accreditation Process

All the Professional Bodies represented on the PBWG adopt essentially the same approach to accreditation. They all produce guideline documents based on their interpretation of SARTOR 3, which are published and sent to university departments [3, 4, 5, 6, 7, 8]. They all require academic departments to complete a submission document which is used as the basis for accreditation and arrange for a team to visit the department. In all cases the team produces an assessment pro-forma and after the visit a report is written on the basis of the completed pro-forma for approval by an Accreditation Committee. In some cases the final report is confidential to the Accreditation Committee and in other cases the final report is sent to the university as a formal record of the outcome of the accreditation process.

Submission documents are required in advance of a visit and the adequacy of the documentation and the academic programme that it describes is formally assessed. For example the IMechE requires documentation at least six weeks ahead of a visit and this is reviewed by three Committee members. Inadequate documentation or programme specification can result in the process being suspended and no visit taking place.

Although there is a default format for the visit, most Professional Bodies will tailor a visit to suit the particular needs of the academic programme and to enable the visiting team to address concerns that are identified by the documentation. Generally the visiting team meets with senior university staff that will include the Head of Department and may include the Vice Chancellor, but always they will meet with teaching staff and students. They will inspect individual and group project work and coursework and will visit laboratories, design studios and other areas that support student learning, such as learning resource centres which generally include library provision.

3.3 Assessment of input and output by the Professional Bodies

All the Professional Bodies have established guidelines, developed from SARTOR 3, which identify how they believe an accreditation team should judge an academic programme based on an evaluation of both input and output measures. In all cases, input is assessed through a study of the documentation provided to the Professional Body's accreditation committee by the university, supplemented by the panel visit. Output is assessed through a study of examination papers, group and individual project reports, design and laboratory reports, external examiners reports and student feedback. In all cases discussions take place with staff and students during the accreditation visit and in some cases the accreditation team may also meet with employers of graduates from the academic programme.

> "If a way has been found to rigorously assess university education on output standards then this should be adopted. For me the whole point of such an exercise is to give individuals and those who employ them some means of establishing competence to practice engineering at or above an agreed standard." *Professor Ernest Shannon*

In all cases the assessment described above is based on a peer review process, which is a well-tried and trusted method of judgement and is accepted by both parties as an appropriate method when applied with due care and professionalism. The assessment is based on the codification of the criteria and the transparent use of these criteria in coming to a judgement. Generally it is supported by the careful selection, training and probation of accreditors. Under these conditions the Professional Engineering Bodies believe that it is possible to undertake accreditation on the grounds that they can establish, through peer assessment, whether or not the criteria have been met.

Decisions on whether or not graduates meet required standards are based largely on the principle of connoisseurship - where the decision relies on the judgement of expert assessors. As far as one can tell, most Professional Engineering Bodies do not use explicit exemplar benchmarks and do not attempt to compare the actual output being achieved against benchmarked standards. However the use of benchmarks would allow decisions to be made in a much more explicit manner based on judgement.

> "The basis of the judgement should be more explicit and not be mere declaration in which case, it is opinion rather than judgement. After all art and wine connoisseurs are nowadays expected to explain their judgements eg nose - what aromas; taste - what flavours; finish - does it linger, etc. Not sufficient to say 'I like it' if you declare you are a wine expert. The wine experts use benchmark exemplars eg blackberries, leather, etc or comparators eg this Chilean red is reminiscent of St Emillion. Engineering 'connoisseurs' need to develop their own language." *Professor Jim McQuaid*

However, in spite of the imperfect nature of some of the aspects of accreditation identified above, members of the PBWG were of the opinion that on the whole the process was robust, but all agreed that the assessment of graduate output could be improved by the use of a standard such as the EPC Output Standard.

3.4 Approaches to Accreditation by the Professional Bodies

Since the introduction of SARTOR 3 Professional Bodies have been busy developing accreditation procedures that are designed to be more innovative and flexible, whilst at the same time having regard for the input and output standards set out in SARTOR 3. The rapidly changing nature of engineering has been an important driver of this process and the perceived need by some Professional Bodies to assess output in a more explicit way rather than an over-emphasis on input. The Professional Bodies have clearly developed methodologies for attempting to assess both input and output. This section describes some of the innovations that have been developed for attempting to assess output.

The Institute of Marine Engineering, Science and Technology (IMarEST) has carried out a significant amount of work to establish output criteria and has produced a matrix of 'Ability to…Statements' linked to SARTOR 3 requirements which differentiates between the levels of attainment required for different degree awards. However they have not yet moved to the stage where they invite programme providers to show how they meet the criteria set out in the matrix. The matrix has a large number of quite complex statements, which raises an important issue that all standards have in common. A compromise is required between the detail required to express the standard accurately and the need to keep it comprehensible and manageable by those who will need to use it.

The British Computer Society (BCS) uses seven major criteria in making a judgement. Three of these relate to the department and the learning environment (quality assurance, staffing and resources) and four relate to the individual academic programmes (aims and philosophy; legal, social, ethical and professional issues; projects and assessment, entry qualifications and graduation profiles). Each of these sections is further divided into six or so subsections. The

Society requires academic programmes to be described using the QAA Programme Specification. They specifically ask for details on how the Programme meets the QAA Computing Benchmark Statement. In this way BCS is attempting to reduce the accreditation load on universities by reducing duplication.

The BCS has also moved away from specifying a core component of curriculum, apart from requiring legal, social, ethical and professional issues to be addressed. They have recognised that specifying a core reduces flexibility in an environment that is changing rapidly both in terms of the content of programmes and the type of programmes that the BCS wish to accredit. As with most Professional Bodies the BCS places great emphasis on design and pays a lot of attention to this when visiting a university. Again as with most other professional bodies they use a checklist system, but failure to meet one of the criteria does not necessarily mean that accreditation will be withheld. One of the criteria is the SARTOR 3 entry standard.

The Institution of Electrical Engineers (IEE) also places significant emphasis on clear aims and objectives for the academic programme and these are used as the main driver for a visit. They have a system in which eight identified elements of the programme are scored on a scale of 1 to 4 similar to the former Teaching Quality Assessment approach. If any one element scores 2 or less the programme is not fully accredited. The IEE recognises that there are conflicting priorities that need to be resolved when developing engineering programmes and they attempt to assure themselves that this has been done in a reasonable and balanced way. For example the IEE are well aware of the conflict between the need to produce graduates who are able to apply the technology of today and who are immediately employable and the need to provide graduates with a good and sound grounding in the fundamental principles of mathematics and relevant science and who can invent and develop the technologies of the future.

The Institution of Incorporated Engineers (IIE) places significant emphasis on project work and activities and investigates both process and outcomes in this area. They regard this as a very reliable measure of graduate output. The assessors carry out a desk audit of the submitted documentation prior to the visit and their report is used to focus the content of the visit meetings. They have been able to engage in joint validation/accreditation procedures successfully, thus reducing the workload on universities.

The Joint Board of Moderators (JBM) attempts to assess input and output aspects of the provision. They particularly like to see involvement of practising engineers in the area of design. They like to adopt a broad non-confrontational approach to visits and they do not like to just tick boxes or ‘nit pick’, but rather to assess the overall flavour of the programme. However they state that they are strict on admission standards and have introduced minimum levels of 18 A-level points for MEng and 16 A-level points for BEng as well as imposing the SARTOR 3 averages.

The Institution of Mechanical Engineers (IMechE) guideline documentation refers to output standards and lists a number of ‘Ability to…Statements’ closely aligned to those in SARTOR 3. As with other Professional Bodies the IMechE attempts to assess these through discussions with students, graduates and employers, a review of projects, design work and examination papers and a study of external examiners’ reports. However the ‘Ability to…Statements’ and other outputs are not benchmarked. Otherwise the IMechE engages in the accreditation process in a similar manner to the other Professional Bodies. The IMechE is currently reviewing its accreditation procedures and intends to rewrite its Educational Base Document.

Although not members of the PBWG it was brought to our attention that the Institution of Chemical Engineers (IChemE) has just (January 2002) published draft accreditation guidelines based on learning outcomes. The document identifies required learning outcomes covering the aspects of knowledge and understanding, intellectual abilities, practical skills and general transferable skills. Without attempting to specify a detailed core curriculum, the document states the required learning outcomes for Chemical Engineers and identifies the methods of assessing the achievement of these outcomes through examination papers and projects, design and laboratory reports. In general terms the core of chemical engineering is identified and, for guidance purposes only, the minimum academic credits required to cover this core for both the BEng(Hons) degree and the MEng are stated. Interestingly, and in line with a possible approach being considered by the PBWG, the document presents three different types of design assignments in terms of learning outcomes and identifies ways in which these outcomes may be evidenced.

3.5 Reasons for withholding Accreditation

The Working Group felt that it was important to identify reasons for withdrawing or withholding accreditation. What follows is a summary of the discussions and identifies a number of deficiencies that may lead to an unfavourable accreditation outcome.

Accreditation is not given to a programme when serious deficiencies are identified in relation to the relevant accreditation guidelines produced by the various Professional Engineering Bodies. Nearly all these deficiencies are related to input and it is expected that they can be identified during the initial review of the submission documentation. The accreditation process may then cease at this stage. However if this is not the case and recoverable deficiencies are identified during the visit stage, accreditation may be awarded for a limited period on the condition that the deficiencies are formally addressed to the satisfaction of the Accreditation Committee.

The IIE members of the PBWG stated that sometimes a programme is offered for accreditation with a number of different pathways identified by a clearly defined set of modules. An accreditation outcome may be that some pathways are accredited and others are not due to content deficiencies being identified. In such cases accreditation is not being withheld from the providing department but from some of the courses within the programme in that department.

The BCS may withhold accreditation for a number of reasons including, failure to adequately meet the requirements for coverage of legal, social, ethical and professional issues, projects which are not practical problem solving projects, or honours degrees which appear not to satisfy the honours qualification descriptor in the QAA national qualifications framework. Other issues such as poor quality assurance processes, insufficient resources, as well as the above issues may lead to reduced periods of accreditation and the need for evidence at the end of the reduced accreditation period that the relevant issues have been addressed.

Other deficiencies that may lead to accreditation being withheld or only being awarded for a short time may include such things as:

- identified weaknesses in the curriculum with key aspects missing or optional;
- absence of leadership in a discipline area, or the lack of suitably qualified staff;
- inadequate equipment resources;
- inadequate numbers of technical support staff;
- student numbers that are too small for a viable MEng cohort;
- a student entry qualifications profile that is consistently failing to achieve the required SARTOR 3 admissions standard.

To summarise, therefore: accreditation may be withheld, withdrawn or given for a reduced period on deficiencies identified in input or output or both.

4 Mapping of Professional Body Current Practice on to the EPC Output Standard

In an attempt to evaluate the possible use of the EPC Output Standard framework as a means of supporting output standard assessment, the PBWG decided to ask each of the Professional Bodies represented on the Working Group to complete a pro-forma. The pro-forma is attached as Appendix 4. The Professional Bodies represented, agreed to use this pro-forma to attempt to describe methods they would use to assess the 26 'Ability to…Statements', together with their expectations of the levels of these attainments, through the identification of typical exemplar benchmarks which might be used as a basis of assessment that the threshold had been achieved. On the whole, all the Professional Bodies were readily able to identify a range of methods employed to assess 'ability to' output but most found it difficult or were unable to define threshold attainment through typical exemplar benchmarks. Clearly a significant amount of further work would be required by the Accreditation Committees of the various Professional Engineering Bodies before the EPC Output Standard and associated benchmarks could be used in any meaningful way to support the accreditation process.

After attempting to complete the pro-forma there was a long debate about the feasibility and indeed the advisability of attempting to produce exemplar benchmarks as part of this mapping exercise, although there was general agreement that the EPC 'Ability to…Statements' are an appropriate framework for an output standard. However it was felt that if a Professional Body was to produce benchmark exemplars for each of the 'Ability to…Statements', they may not properly reflect the wide variety of possible exemplars likely to be found for each ability. Furthermore, if such benchmarks were to become available in the wrong hands they could be interpreted as prescriptions and followed in a slavish, copycat manner. As such, they might stifle innovation and creativity in programme planning and module development. They could also be used by universities to argue the case for accreditation even though other aspects of the provision were identified as being unacceptable and below the threshold.

> "I agree with the objection raised in the paper to the development of benchmark exemplars that they could promote slavish copycat imitations. A portfolio of exemplar attributes would be preferred than exemplar benchmarks. There are those who will say 'Tell us what to do and don't leave it to us to think'. This was the response of many to goal-setting health and safety legislation!
>
> The experience in the H&S field of the change from prescription eg machine guards, dust masks, etc to goal setting eg risk assessment and avoidance by design, is I think highly relevant to what you are trying to do." *Professor Jim McQuaid*

However it was recognised by members of the PBWG that if progress was to be made in the use the EPC Output Standard by the Professional Engineering Bodies, it would be difficult for accreditation committees to articulate the desired level of attainment that they were expecting for a programme to be accredited if they were unable to provide exemplar benchmarks. It was thought that an alternative approach would be to express a standard in terms of the complexity and open-ended nature of the tasks that graduates were expected to undertake, and that benchmarking a portfolio of exemplar tasks in these terms might be worth exploring. (This may be the approach being adopted by the IChemE as described in the report in Section 3.4 and is the way forward suggested by Professor McQuaid).

> "I think an ability to explain one's judgements is an increasingly important competence for engineers and a structure for doing so should be a part of the curriculum. The medical and legal professions realise this since they deal with problems with no 'right'

answers and weight of evidence, balance of probability etc figure strongly in their decisions. Engineering teaching is based far too much on problems with 'right' answers and assessment based on the student getting the 'right' answer. The poor student is brought rapidly down to earth after graduation when he finds that the problems he deals with are characterised by insufficient information so that judgements have to be exercised. Development of that judgement then takes an unnecessarily long time in career terms since it is not supported by any educational foundation."
Professor Jim McQuaid

All members of the Working Group agreed to continue working on the mapping exercise particularly with respect to the identification of benchmark exemplars.

A comparison was also carried out between the EPC Output Standard 'Ability to…Statements' and the professional competencies and outcome statements in SARTOR 3 set out and referred to in Section 3.1 above. The comparison shows that close correlation exists between the requirements of SARTOR 3 and the 'Ability to…Statements' in the EPC document.

5 A review of Accreditation by non-UK Professional Engineering Bodies

The working Group felt that it was important to have some understanding of the accreditation practices of Professional Engineering Bodies outside the UK. This section of the report attempts to give a brief summary of this limited review.

5.1 European Countries

In many European countries professional accreditation of courses is a relatively recent development. There is however increasing interest being shown in it as higher education structures in many countries change and universities seek third party validation of their programmes. While practice has tended to be based on inputs, there is increasing interest being shown in output measures, although there is generally less experience of using these in relation to higher education than there is in the UK. A recent development is the establishment of a European Standing Observatory for Engineering Professional Education (ESOEPE) which exists to exchange information about accreditation practice in different countries. The current members are UK, France, Germany, Italy and Portugal. Further details of ESOEPE can be found at http://www.feani.org.

5.2 Other Countries

A number of other countries, principally from the English-speaking world, have signed the Washington and/or Sydney Accords which provide for mutual recognition of accredited engineering degrees. These are briefly described in Appendix 5. In many of these countries (eg Australia, New Zealand, South Africa) the approach to accreditation basically follows the UK model. Interest is being shown in using output measures and some preliminary work is being done on these. The chief alternative model of accreditation, used principally in the USA and Canada, is the ABET model and this is described in more detail below.

5.3 The United States Accreditation Board for Engineers and Technologists (ABET)

ABET [9] is recognised by the US Department of Education as the sole agency responsible for the accreditation of educational programmes leading to degrees in engineering and technology and related engineering areas. ABET appears to use an approach similar to that of the

Professional Bodies in the UK, in that it requires a submission document and an accreditation visit by a panel of experts. However it seems to have an overarching role emphasising procedure and process with less of an emphasis on programme content and level of attainment. The individual discipline-specific Institutions in the USA seem to have very little input into the accreditation process. Each has a small section in the criteria specification, which makes the otherwise generic criteria more discipline-specific.

Programmes are assessed against eight criteria presented under the headings of students, programme educational objectives, programme outcomes and assessment, professional component, faculty (academic staff), facilities, institutional support and financial resources and programme criteria.

Of particular interest to the Working Group was the reference in the ABET document to output and how this is assessed. Under the heading of Programme outcomes and assessment, ABET does address the output of graduates by specifying eleven output measures with eight of these containing an 'Ability to…Statement'. This list is quoted in full as follows:

Engineering programmes must demonstrate that their graduates have:

(a) an ability to apply knowledge of mathematics, science and engineering
(c) an ability to design and conduct experiments, as well as analyse and interpret data
(d) an ability to design a system, component or process to meet desired needs
(e) an ability to function in multidisciplinary teams
(f) an ability to identify, formulate, and solve engineering problems
(g) an understanding of professional and ethical responsibility
(h) an ability to communicate effectively
(i) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(j) a recognition of the need for, and an ability to engage in life long learning
(k) a knowledge of contemporary issues
(l) an ability to use techniques, skills, and modern engineering tools necessary for engineering practice

This criterion also states that 'each programme must have an assessment process with documented results'. Evidence must be given that the results are applied to the further development and improvement of the programme. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the programme, including those listed above, are being measured. Evidence that may be used includes, but is not limited to the following: student portfolios, including design projects; nationally-normed subject content examinations; alumni surveys that document professional accomplishments and career development activities; employer surveys; and placement data of graduates.

Compared to the EPC Output Standard and some of the expectation of UK Professional Body accreditation requirements, this is a very abbreviated statement although it is presented in the familiar 'ability to' format. It does not give levels of attainment or benchmarks for the 'Ability to…Statements' and there are only three statements addressing technical content requirements. However, it is very definite about the requirement for the abilities to be evidenced and to be in a form that is consistent with the mission statement of the institution and the objectives of the programme.

More details of the ABET approach can be found on the Website: http://www.abet.org.

5.4 Other non-UK Professional Bodies in the EU

As far as non-UK Professional Bodies are concerned, it was confirmed that activity is sparse and it seems that most are following either UK or US accreditation practice. In particular it is believed that EU activity is still in its early stages of development although more information is required to confirm this. However the Working Group was informed that developments were taking place and, where this was happening, the use of output standards was being actively pursued. This was on the basis of reports received from CEPIS (Committee of European Professional Information Systems) and from ESOPE (Observatory on European Accreditation Practice).

6 Review of Output Standards of other relevant UK Professions

To understand the accreditation practices of other UK professions, the PBWG obtained information on the processes used by a number of the major professions and in particular how they dealt with the assessment of output. The professions identified for study were nurses, medical practitioners, accountants and lawyers. Appendix 6 gives a brief summary of the information obtained, relevant to the aim of the PBWG, gained from a study of these professions using published literature, public reports and discussions with key individuals. Other information was obtained from papers of the UK Inter-Professional Group. It is clear that all the professions use accreditation practices that have strong similarities to those being used by the engineering profession. It is of interest to note that they are all examining, to different extents, how the ability and capability of the graduate output can best be assured to improve professional competency. This is particularly urgent in the health professions, largely as a consequence of the recent (January 2002) report into children's heart surgery at the Bristol Royal Infirmary. In response to the findings from this report, the GMC is totally reviewing undergraduate medical education. This is resulting in a stronger focus on learning objectives and outcomes and identifying approaches for the assessment of the competency of students and graduates.

Another example is that of the accountancy profession. In a recent review of the academic requirements for membership of the Institute of Chartered Accountants in England and Wales, professional stage syllabus learning outcomes are specifically included and are presented in the 'ability to' format.

Furthermore the Law Society is conducting a review of the training framework for solicitors, and this is based very strongly on the idea of a grid of competencies. At the present, this is still at an early stage, but will no doubt impact upon the way initial qualification requirements are stated.

From the information studied on the various professional bodies and illustrated by the examples above, it is evident that many professional bodies in the UK are attempting to assess the ability and capability of graduates through a greater focus being placed on the assessment of output.

7 The QAA approach to setting standards and a comparison with the EPC Output Standard

The Quality Assurance Agency (QAA) has produced a number of documents that set out a generic framework for setting standards in Higher Education programmes. Three documents are key to the discussion of the Working Group. Since there is no doubt that these will have a direct impact on the way in which university engineering departments prepare their programmes and maintain their programme provision, it was felt by members of the Working Group that a section on the QAA work should be included in this report. In fact it was brought to the attention of the Working Group that the BCS now requires university departments to submit a programme specification as part of their accreditation process. The Working Group does not however intend to duplicate the work of the Joint EPC/QAA Compatibility Working Group which has been specifically requested to study the QAA and EPC approaches in depth.

The four key documents are:

- The Framework for Higher Education Qualifications in England, Wales and Northern Ireland (The QAA Qualifications Framework) [10]
- Academic Standards – Engineering (The QAA Benchmarks) [11]
- Academic Standards – Computing (The QAA Benchmark) [12]
- Guidelines for Preparing Programme Specifications (The QAA Programme Specification) [13]

The QAA Qualifications Framework contains high level descriptors of all the qualifications offered by Higher Education. The two descriptors most relevant to Engineering are the Bachelors degree with Honours and the MEng. QAA acknowledges the MEng as an undergraduate programme with output at masters level that lasts, typically, a year longer than honours degree programmes.

Of particular relevance to PBWG are the QAA's documents on Engineering and Computing subject benchmarking. The QAA brief for these documents was to produce 'generic' statements which represent general expectations about standards for the award of honours degrees in Engineering and in Computing. The documents define respectively Engineering and Computing and the skills, attributes and qualities of an engineer and computing specialist in terms of knowledge and understanding, intellectual abilities, practical skills and general transferable skills. Having defined these qualities, they go on to define, in general terms, content, delivery and attainment. The QAA is working on an appendix to the BEng (Hons) document that provides more guidance on MEng degrees.

The QAA Programme Specification is a set of guidelines that offer help to university departments which are preparing descriptions of academic programmes. A programme specification is a concise description of the intended outcomes of learning from a higher education programme, and the means by which these outcomes are achieved and demonstrated. The development of programme specifications is in response to the recommendation from the Report of the National Committee into Higher Education (The Dearing Report). In future all HE programmes will be required to be defined in terms of programme specifications and the QAA document gives an example of a Cambridge University BA (Hons)/MEng Programme defined in this way. The BCS is requiring specifications for all programmes submitted to them for accreditation as a means of reducing the workload on university departments.

The Working Group compared the EPC Output Standard with both the QAA Engineering and the QAA Computing Benchmark Statements.

It is clear that the Engineering Benchmark and the EPC Output Standard both focus on the same area and there are close similarities in the structure of the approach. Both documents are based on a list of abilities that engineering graduates are expected to acquire and these in turn are based on the procedures carried out by engineers in the delivery of engineering projects. The

EPC sets out its list of abilities in the context of the engineering process and in terms of what a graduating engineer may be expected to be able to do, whereas the QAA approach identifies graduate capabilities in terms of knowledge and understanding, intellectual abilities, practical and general transferable skills associated with the areas of Mathematics, Science, Information Technology, Business Context and Engineering Practice.

Thus the EPC standard is couched in terms which explicitly reflect abilities associated with the definition and solution of engineering problems with the necessary underpinning knowledge and skills implied, whereas the QAA approach is structured more to suit the assessment of their performance within the subject areas identified above. Another difference in approach emerges in the description of the level at which the abilities are attained. The QAA Engineering Benchmark has three general level descriptors for each ability which are threshold, good and excellent and differentiates between achievement at these three levels by statements such as 'has basic knowledge; has basic knowledge and understanding; has comprehensive understanding'. In comparison the EPC Output Standard identifies a threshold through an 'Ability to…Statement' and illustrates its achievements by exemplar benchmarks.

The QAA Computing Benchmark differs from the Engineering Benchmark, in that it does not address the content of computing degree programmes, rather it identifies a broad set of curriculum areas and issues related to course design. However, the two benchmarks are very similar in identifying the abilities expected of graduates in the two discipline areas. The Computing Benchmark breaks the abilities into three broad areas – computing-related cognitive skills, computer-related practical skills and transferable skills. Although the language is not the same as that used in the EPC Output Standard, there are many similarities. As such, it is relatively easy to equate the 'Ability to…Statements' in the Computing Benchmark to those in the EPC Output Standard. The Computing Benchmark has only two generic level descriptors – threshold and modal. The comparison made between the EPC Output Standard and the Engineering Benchmark above thus holds true for the Computing Benchmark.

The specification of level is an essential element of the specification of a standard that, after all, is an expected or actual level of attainment. It is needed to make any sense of the Qualifications Framework in the context of engineering. BSc and BEng honours degrees are supposed to be at the same level according to the Qualifications Framework, but are also to be used in various ways to lead to the professional qualifications of IEng and CEng, which are different in nature, although not in level, according to the Engineering Council. The MEng has to be at masters level and is for the Professional Bodies the exemplar academic qualification for CEng. As stated above the QAA is currently producing guidance on the interpretation of the Engineering benchmark in the context of the MEng.

The report from the Joint EPC/QAA Compatibility Working Group establishes the compatibility of the QAA Academic Standard – Engineering and the EPC Output Standard. It concludes that they do not contradict each other but say very similar things, although in different formats. The report observes that opportunities will arise, in the not too distant future, for the principal stakeholders to determine whether the standards, including SARTOR 3, should be co-ordinated in some formal manner, or whether the retention of these different, but compatible perspectives for characterising what is expected of a graduate engineer provides opportunity and flexibility. The PBWG agrees that in any review of output standards all three documents should be considered but takes the view that in the long term harmonisation of the three approaches to output standards would in fact be very helpful to the accreditation process.

8 Possible impact on Accreditation of the QAA and EPC Standards

If all HE academic programmes of study are to be defined in terms of the QAA programme specifications document and, as QAA expects, universities are to use the Benchmarking Statements as a point of reference in designing and validating engineering programmes of study, duplication and hence workload would be reduced if the accreditation process included the use of this information in their required documentation. In fact, the BCS now requires universities to submit a programme specification for programmes submitted to them for accreditation. Taking into account the comparison of the QAA and EPC approaches to assessing graduate output given in Section 7, the Professional Bodies will need to decide which approach is more likely to provide the information required to allow them to make sound and defensible accreditation decisions.

However, no matter which approach succeeds in becoming the accepted norm, it is clear that the Professional Body Accreditation Committees will need to engage more with output standards, benchmarking and assessment. An understanding of these issues will enable the accreditation teams of the Professional Bodies to use these as an important and integral part of the accreditation process.

9 General Observations

- Four output standards are relevant to the work of Engineering Professional Bodies in their accreditation processes. These are: the two QAA Benchmarks relating to Computing and Engineering, SARTOR 3 and the EPC Output Standard. In any review of output all four documents should be considered.

- Throughout the PBWG discussions it was clear that there was significant commonality between the approaches used by the various Professional Engineering Bodies in their accreditation practices.

- All Professional Engineering Bodies assess a mixture of input and output criteria when considering the accreditation of academic programmes. However assessment of input is better established than the assessment of output.

- Some of the Professional Engineering Bodies are moving towards to the explicit assessment of output in their accreditation procedures. Recently developed accreditation documentation from the IMarEST and IChemE concentrates on the assessment of output.

- Many non-engineering Professional Bodies in the UK are moving towards the assessment of output in their approaches to improving the competency of their members and potential members.

- ABET uses ‘Ability to…Statements’ in its accreditation documentation.

- Accreditation within Europe is at an early stage of development.

- All members of the PBWG found it difficult to identify exemplar benchmarks through the mapping exercise described in Section 4 although they readily identified the methods they used to assess output.

10 Recommendations

Although members of the PBWG were strongly of the opinion that the current approaches to academic programme accreditation were robust, it was agreed that there was room for continuous improvement particularly in the assessment of graduate output. This improvement would be achieved through the acceptance of the following five recommendations:

<u>Recommendation 1</u>

The Engineering Council is urged to instigate a dialogue between itself, QAA, EPC and the Professional Engineering Bodies with a view to harmonising the three approaches to output standards so as to allow accreditation committees to make sound judgements using output criteria.

[ACTION: Engineering Council]

<u>Recommendation 2</u>

Professional Engineering Bodies are encouraged to move away from a concentration on the assessment of input to a more explicit use of agreed output criteria where appropriate and possible.

[ACTION: Professional Bodies]

<u>Recommendation 3</u>

Professional Engineering Bodies are urged to work on a mapping exercise to produce appropriate exemplar benchmarks and/or attributes to support the accreditation process in the assessment of graduate output.

[ACTION: Professional Bodies]

<u>Recommendation 4</u>

The Professional Engineering Bodies should work together through DABCE and JAB in order to harmonise the various accreditation processes used. This is of particular importance as the shift towards the assessment of graduate output occurs

[ACTION: DABCE and JAB]

<u>Recommendation 5</u>

The EPC should monitor the progress on the four recommendations and report progress to its annual Congress in 2003.

[ACTION: EPC]

11 References

1 The EPC Graduate Output Standard, Interim Report of the EPC Output Standard Project, EPC Occasional Paper No. 10, December 2000.

2 Standards and Routes to Registration - SARTOR, 3rd Edition 1997, An Engineering Council Policy Document.

3 The Institution of Mechanical Engineers, The Educational Base, The Formation of Mechanical Engineers, Revised June 1999, (Currently being revised). (Email: degreeaccreditation@imeche.org.uk)

4 The British Computer Society, Guidelines on Course Exemption and Accreditation, Information for Universities and Colleges, August 2001. (http://www.bcs.org.uk/educ.htm)

5 The Institution of Incorporated Engineers, Accreditation Information Pack, December 2000. (http://www.iie.org.uk/education/indexnm.asp?page=1)

6 The Joint Board of Moderators, (The Institution of Civil Engineers, The Institution of Structural Engineers and the Chartered Institution of Building Services Engineers), Accreditation Edition, 12.08.98, Briefing File, July 2000)

7 The Institution of Marine Engineering, Science and Technology, The Formation of Marine Engineers, The Standards and Procedures Document, 12.10.99 (Email: dml@imare.org.uk)

8 The Institution of Electrical Engineers, The IEE's response to SARTOR 3rd Edition (1997), 3 August 1998, (htp://www.iee.org/Membership/Join/SARTOR/sartor97.cfm) (Email: accred@iee.org.uk)

9 Accreditation Board for Engineering and Technology, (ABET), Criteria for Accrediting Engineering Programs, 1 November 2000, (http://www.abet.org), Email:accreditation@abet.org).

10 The Quality Assurance Agency for Higher Education, The framework for higher education qualifications in England, Wales and Northern Ireland – January 2001, (http://www.qaa.ac.uk/crntwork/nqf/ewni2001/textonly.htm)

11 The Quality Assurance Agency for Higher Education, (http://www.qaa.ac.uk), Academic standards – Engineering

12 The Quality Assurance Agency for Higher Education, (http://www.qaa.ac.uk), Academic standards - Computing

13 The Quality Assurance Agency for Higher education, Guidelines for the preparing programme specifications, (http://www.qaa.ac.uk)

Appendix 1

Rationale and Terms of Reference for Professional Body Working Group

1 Context

Work on the EPC Engineering Output Standard continues in pursuit of the aims defined by EPC members. Phases 1 & 2 of the work to define a framework for the standard are largely complete and are a subject of an Interim Report entitled EPC Occasional Paper Number 10, December 2000.

The EPC Committee has recently approved Phase 3 of the work with the following aims:

- To build widespread acceptance of the EPC Standard as the preferred method of specifying and comparing the achievement of engineering graduates;
- To link and converge the EPC Standard with other National Standards, particularly the QAA Engineering Benchmarks;
- To foster the process of development and peer review of discipline-specific benchmarks, thereby clarifying and consolidating the level of expected graduate ability;
- To establish and articulate employer expectation of graduates in relation to and using the 'language' of the EPC Output Standard.

Phase 3 will comprise five linked sub-projects. One of these is a project on accreditation by professional bodies. The others are to do with assessment, convergence with QAA benchmarking, the relationship with employers, and IEng benchmarking.

2 EPC Engineering Output Standard Project – Phase 3 (Professional Bodies Sub-Project Working Group)

The overall aim of the sub-project is to encourage the peer-review of benchmarks in relation to the EPC Engineering Output Standard and to explore the benefits to accrediting bodies of a single standard applicable across all engineering disciplines.

It is proposed to achieve this aim by:

- identifying ways in which the EPC Engineering Output Standard can be used to aid and support the accreditation processes used by the accrediting bodies;
- supporting professional engineering body accreditation committees in the effective and efficient use of the EPC Engineering Output Standard in the accreditation processes employed;
- encouraging the use of the EPC Engineering Output Standard by the Professional Engineering Bodies.

3 Professional Bodies Working Group – Terms of Reference

A Professional Bodies Working Group is to be established with the following draft Terms of Reference. These terms of reference will be discussed at the first meeting of the Working Group and changed if necessary and appropriate:

1. To pursue the aim of the EPC Engineering Output Standard Professional Bodies sub-project which is to encourage the peer-review of benchmarks in relation to the EPC Engineering Output Standard and to explore the benefits to accrediting bodies of a single standard applicable across all engineering disciplines.

2. To receive advice from the EPC Output Standard Advisory Group and EPC Output Standard Co-ordinating Group;

3. To discuss the questions raised in the Appendix to these Terms of Reference and any others that might be identified as the result of these discussions;

4. To produce exemplar accreditation benchmark statements against the EPC Output Standard;

5. To report progress to the EPC Committee through the EPC Output Standard Co-ordinating Group;

6. To produce a final report on the outcomes from the Working Group for the EPC Output Standard Co-ordinating Group;

7. To disseminate outcomes from the Working Group to the accrediting bodies and the overarching accreditation co-ordinating groups, via the EPC.

Questions that might be addressed by the Working Group

In order to achieve the aims of the sup-project the following questions might be addressed by the Working Group:

What constitutes good accreditation practice in the present context?

- How does each accrediting body currently deal with the accreditation of courses?
- Are there examples of good practice nationally, internationally and in other disciplines?
- What is the current balance between the assessment of input measures, process and output standards?
- How are output standards currently assessed and evaluated?
- What examples of good practice are available for assessing output standards?
- What are the barriers to the universal application of best practice?

What changes in accreditation practice are implicit in the present QAA Programme Specification and Benchmark Standards, and QAA Qualifications Framework?

- Will accrediting bodies use the QAA Programme Specification and Benchmark Standards, or Qualifications Framework, in support of the accreditation process?
- How will the QAA Programme Specification and Benchmark Standards, or Qualifications Framework, be used by the accrediting bodies when assessing engineering courses and programmes?

What changes in accreditation practice are implicit in the use of the EPC Engineering Degree Output Standard?

- How would accrediting bodies wish to use the EPC Engineering Degree Output Standard to assess whether a course or programme is acceptable for accreditation at either CEng or IEng levels?
- What is the role of accreditation in the assessment process?
- What critical issues does the use of a threshold output standard raise in the accreditation processes used by the accrediting bodies?
- How would the accrediting bodies wish to change their accreditation processes to incorporate the assessment of threshold output standards?
- What would be the implications for the use of SARTOR as currently framed?

How can good accreditation practice, appropriate to the use of the output standard, best be identified, developed and disseminated across the accrediting bodies?

- Is there a case for some form of common approach or framework?
- What are the barriers to a common approach?
- What should be the role of the overarching accreditation co-ordinating groups in this process?
- Does the EPC Output Standard provide an opportunity for the accrediting bodies to communicate more effectively with stakeholders including Industry, HE and FE?

What are the barriers to applying the EPC Engineering Output Standard to the accreditation process of the accrediting bodies?

- How can any identified be overcome?

What are the next steps?

Accrediting bodies to produce exemplar benchmark statements against the EPC Standard for disciplines within their scope of influence.

The process will involve:

- disseminating outcomes from the Working Group;
- informing accrediting bodies by seminars;
- promoting feedback between accrediting bodies about benchmark requirements

Appendix 2

Membership of Professional Bodies Working Group

Mr David Eaton (Chair)	(IMechE) Sheffield Hallam University
Prof Gordon Bull	(BCS)
Mr Peter Cannings	(IIE)
Dr John Chudley	(IMarEST) University of Plymouth
Mr Phil Cooper	(JBM) Harris and Sutherland, Cambridge
Prof Nicos Ladommatos	(IMechE) Brunel University
Rev Stuart Poole	(IIE)
Richard Shearman	Engineering Council
Prof DG (Geoff) Smith	(IEE) University of Strathclyde
Prof Jim White	(Secretary and EPC)

Appendix 3

List of Professional Engineering Bodies licensed by the Engineering Council

Institute of Acoustics
Royal Aeronautical Society
Institution of Agricultural Engineers
Chartered Institution of Building Services Engineers
Institute of Cast Metals Engineering
Institution of Chemical Engineers
Institution of Civil Engineers
British Computer Society
Institution of Electrical Engineers
Institute of Energy
Institution Engineering Designers
Society of Environmental Engineers
Institution of Fire Engineers
Institution of Gas Engineers and Managers
Institute of Healthcare Engineering and Estate Management
Institute of Highway Incorporated Engineers
Institution of Incorporated Engineers
Institution of Lighting Engineers
Institute of Marine Engineering, Science and Technology
Institute of Materials
Institute of Measurement and Control
Institution of Mechanical Engineers
Institution of Mining and Metallurgy
Royal Institute of Naval Architects
British Institute of Non-Destructive Testing
Institution of Nuclear Engineers
Society of Operations Engineers
Institute of Physics
Institute of Physics and Engineering in Medicine
Institute of Plumbing
Institution of Railway Signal Engineers
Institution of Structural Engineers
Chartered Institution of Water and Environmental Management
Institution of Water Officers
Welding Institute

Appendix 4

Mapping of 'Ability to…Statements' with output assessment methods employed by Professional Bodies

Professional Engineering Body ………………………………………………………………………………

	Generic 'Ability to…Statement'	Method(s) used to assess 'ability to' (indicate using numbers given on page 1 of note)	Typical exemplar benchmarks used to assess that the threshold level has been reached
1.2.1	**Ability to exercise Key Skills in the completion of engineering-related tasks at an appropriate level**		
(a)	Communication	(a)	
(b)	IT	(b)	
(c)	Application of Number	(c)	
(d)	Working with others	(d)	
(e)	Problem Solving	(e)	
(f)	Improving own learning and performance	(f)	

Mapping of 'Ability to…Statements with output assessment methods employed by Professional Bodies

Professional Engineering Body ………………………………………………………………………………

	Generic 'Ability to…Statement'	Method(s) used to assess 'ability to' (indicate using numbers as on page 1 of note)	Typical exemplar benchmarks used to assess that the threshold level has been reached
1.2.2	**Ability to transform existing systems into conceptual models**		
(a)	Elicit and clarify client's true needs	(a)	
(b)	Identify, classify and describe engineering systems	(b)	
(c)	Define real target systems in terms of objective functions, performance specifications and other constraints (ie define the problem)	(c)	
(d)	Take account of risk assessment, and social and environmental impacts, in the setting of constraints (including legal, and health and safety issues)	(d)	
(e)	Select, review and experiment with existing engineering systems in order to obtain a database of knowledge and understanding that will contribute to the creation of specific real target systems.	(e)	
(f)	Resolve difficulties created by imperfect and incomplete information	(f)	
(g)	Derive conceptual models of real target systems, identifying the key parameters	(g)	

Mapping of 'Ability to…Statements' with output assessment methods employed by Professional Bodies

Professional Engineering Body ....

	Generic 'Ability to…Statement'	Method(s) used to assess 'ability to' (indicate using numbers as on page 1 of note)	Typical exemplar benchmarks used to assess that the threshold level has been reached
1.2.3	**Ability to transform conceptual models into determinable models**		
(a)	Construct determinable models over a range of complexity to suit a range of conceptual models	(a)	
(b)	Use mathematics and computing skills to create determinable models by deriving appropriate constitutive equations and specifying appropriate boundary conditions	(b)	
(c)	Use industry standard software tools and platforms to set up determinable models	(c)	
(d)	Recognise the value of Determinable Models of different complexity and the limitations of their application	(d)	

Mapping of 'Ability to…Statements' with output assessment methods employed by Professional Bodies

Professional Engineering Body ....

	Generic 'Ability to…Statement'	Method(s) used to assess 'ability to' (indicate using numbers as on page 1 of note)	Typical exemplar benchmarks used to assess that the threshold level has been reached
1.2.4	**Ability to use determinable models to obtain system specifications in terms of parametric values**		
(a)	Use mathematics and computing skills to manipulate and solve determinable models; and use data sheets in an appropriate way to supplement solutions	(a)	
(b)	Use industry standard software platforms and tools to solve determinable models	(b)	
(c)	Carry out a parametric sensitivity analysis	(c)	
(d)	Critically assess results and, if inadequate or invalid, improve knowledge database by further reference to existing systems, and/or improve performance of determinable models	(d)	

Mapping of 'Ability to…Statements' with output assessment methods employed by Professional Bodies

Professional Engineering Body ....

	Generic 'Ability to…Statement'	Method(s) used to assess 'ability to' (indicate using numbers as on page 1 of note)	Typical exemplar benchmarks used to assess that the threshold level has been reached
1.2.5	**Ability to select optimum specifications and create physical models**		
(a)	Use objective functions and constraints to identify optimum specifications	(a)	
(b)	Plan physical modelling studies, based on determinable modelling, in order to produce critical information	(b)	
(c)	Test and collate results, feeding these back into determinable models	(c)	

Mapping of 'Ability to…Statements' with output assessment methods employed by Professional Bodies

Professional Engineering Body ....

	Generic 'Ability to…Statement'	Method(s) used to assess 'ability to' (indicate using numbers as on page 1 of note)	Typical exemplar benchmarks used to assess that the threshold level has been reached
1.2.6	**Ability to apply the results from physical models to create real target systems**		
(a)	Write sufficiently detailed specifications of real target systems, including risk assessments and impact statements	(a)	
(b)	Select production methods and write method statements	(b)	
(c)	Implement production and deliver products fit for purpose, in a timely and efficient manner	(c)	
(d)	Operate within relevant legislative frameworks	(d)	

Mapping of 'Ability to…Statements' with output assessment methods employed by Professional Bodies

Professional Engineering Body ....

	Generic 'Ability to…Statement'	Method(s) used to assess 'ability to' (indicate using numbers as on page 1 of note)	Typical exemplar benchmarks used to assess that the threshold level has been reached
1.2.7	**Ability to critically review real target systems and personal performance**		
(a)	Test and evaluate real systems in service against specification and client needs	(a)	
(b)	Recognise and make critical judgements about related environmental, social, ethical and professional issues	(b)	
(c)	Identify professional, technical and personal development needs and undertake appropriate training and independent research	(c)	

Appendix 5

Brief details of the Washington and Sydney Accords

1 Washington Accord

This is an agreement between the UK, USA, Canada, Hong Kong, Australia, New Zealand, Ireland and South Africa and was signed in Washington in 1989.

It arose because there had been reciprocal accreditation of each countries engineering degrees – much of it undertaken by the UK following requests from the other countries – from which it became clear that the procedures for accreditation being followed by all the countries was similar. It was also helped by the fact that in all the countries, engineering degree courses are based on the British system.

Mutual accreditation had also given comfort as to the standard of such courses as well as the process, and therefore by the signing of the agreement, each country would recognise the education base of the degree courses of the signatory countries. Provision is made in the agreement for any country to visit another and verify the process and standards, although in practice this has not happened to a significant degree.

2 Sydney Accord

This is a more recent provisional agreement, based on the same countries as the Washington Accord, but concentrating on what we would describe as Incorporated Engineers. Its intent is similar to that of the Washington Accord and its name derives from the fact that the agreement to establish this was signed in Sydney.

Appendix 6

Brief details of developments in accreditation and assessment of output in other UK non-engineering professions

1 Medical Doctors

The General Medical Council is charged by Section 5 of the Medical Act 1983 with the responsibility for "determining the extent of the knowledge and skill which is required for the granting of primary UK qualifications". The act requires it to ensure "that the instruction given in universities in the UK to persons studying for each qualification is sufficient to equip them with the knowledge and skills of that extent." Section 5(3) goes onto say that the GMC's determinations "shall be embodied in recommendations which may be directed to all or any of the universities or other bodies concerned with medical education". The Education Committee of the GMC is charged by statute with responsibility for "promoting high standards of medical education and co-ordinating all stages of medical education".

'Tomorrow's Doctors: Recommendations on Undergraduate Medical Education' (1993) is the key document, although it is currently being revised. The recommendations embodied in this document relate to that part of training which is encompassed during the undergraduate years in medical school.

This had as its objective the reduction of curriculum overload, and encouraged universities and medical schools to identify a core curriculum and means of delivery, which might be supplemented by special study modules or electives, to allow medical students to express choice and explore particular interests. The report sets out key knowledge skills and attitudinal objectives, specifying student achievement on completion of the undergraduate course through the attainment of thirty-six attributes. Many of these attributes are presented in the 'ability to' format. For example 'the ability to exercise sound clinical judgement, to analyse symptoms and physical signs in pathophysiological terms, to establish diagnoses, and to offer advice to the patient taking account of physical, psychological, social and cultural factors'. How these attainments are assessed in terms of level supported by exemplar benchmarks marks is not evident from the documentation studied.

The Medical Act and subsequent statutory instruments list the universities whose qualifications will be accepted for registration purposes. The GMC has the power to recommend to the Privy Council that universities be removed from the list if their provision is unsatisfactory. Universities are monitored through a regular programme of visits, and must by statute respond to the GMC's observations and recommendations about their provision. However, unlike the accreditation process in engineering, the review appears to be institutional rather than specific to courses. The visit reports by the GMC are in the public domain, on the website. Ever since the publication of 'Tomorrow's Doctors' the GMC has directed these visits towards monitoring what progress universities have made towards implementing its principal recommendations. Visit reports do therefore contain observation on how the delivery of essential skills is being addressed. However the reports are not written in any way that delivers a yes or no verdict on individual universities.

2 Nurses

The Department of Health in England is contracting with the QAA for the development and organisation of a process to review health profession academic programmes that lead to professional registration (Reference A). These programmes include time spent in clinical practice and are analogous to a graduate apprenticeship scheme and the way in which the school teaching profession has moved to putting more of the educational base into the classroom. Nurses, for example, qualify after spending 2400 hours in clinical practice settings following an educational base equivalent to a Diploma of Higher Education.

Anticipating this development the United Kingdom Central Council (UKCC) for Nursing, Midwifery and Health Visiting established a Commission for Education under the chairmanship of Sir Leonard Peach. In its report, Fitness for Practice, (Reference B), the Commission recommended the construction of standards required for the registration of nurses in terms of benchmarked outcome competencies which were consistent with the QAA's thresholds for degrees and diplomas.

In August 2000, the Secretary of State approved new UKCC 2000 No. 2554 rules for Nurses training, (Reference C). These rules contain a Schedule listing of twenty outcomes to be achieved within a one-year Common Foundation Programme and a further seventeen outcomes to be achieved at the end of the two year Branch Programme and for entry to Parts 12-15 of the register.

At this stage the Working Group knows little about the way in which these outcomes are assessed although the documentation reviewed indicates that programmes will only be approved if they have:

(a) clear learning outcomes in accordance with the QAA qualifications framework and the relevant benchmark statement;

(b) a curriculum that is designed to enable the intended outcomes to be achieved;

(c) assessment that is effective in measuring achievement of the outcomes;

(d) student achievement that matches the intended outcomes and the level of the qualification.

3 The Legal Profession

Both the Law Society and the General Council of the Bar will recognise completion of a recognised law degree as satisfying the requirements of the initial or academic degree of training. For a degree to be recognised, the HEI providing it must satisfy the professional bodies that adequate learning resources are provided to support the course; that it has degree awarding powers; that the standards of achievement expected are set at or above the minimum level of performance as set out in the QAA Benchmarking statements for Law; and that there is at least one and a half year's coverage (180 credits) of some specified subjects known as the Foundations of Legal Knowledge. However, neither body actually carries out course accreditation. They instead assume that all law degrees will meet these requirements until they have reason to believe otherwise. However, the Bar Council has recently said that the possible attenuation of subject review as a result of changes to QA arrangements for higher education may mean that it will have to undertake its own accreditation in future.

It is worth noting that the Law Society is conducting a review of the training framework for solicitors, and that this is based very strongly on the idea of a grid of competencies. At present this is still at an early stage, but will no doubt impact upon the way initial qualification requirements are stated.

4 Accountancy

The structure of professional recognition in the accountancy profession is, in many ways similar to the engineering profession.

There is no legal licence requirement to practice as an accountant, however the Companies Act 1989 statutorily recognises five qualifying bodies (RQB's) in the UK for company auditors. The five recognised bodies are:

- The Institute of Chartered Accountants of England and Wales (ICAEW)
- The Institute of Chartered Accountants in Scotland (ICAS)
- The Institute of Chartered Accountants in Ireland (ICAI)
- The Association of Chartered Certified Accountants (ACCA)
- The Association of International Accountants (AIA)

Accountancy has a wide range of professional bodies representing the specialist activities within the profession, for example:

- The Institute of Financial Accountants (IFA)
- Association of Cost and Executive Accountants (ACEA)
- Chartered Institute of Public Finance and Accountancy (CIPFA)
- Association of Accounting Technicians (AAT)
- Chartered Institute of Management Accountants (CIMA)

In engineering the educational base for professional registration is achieved through the award of an 'accredited' degree from an Institution of Higher Education, in accountancy the academic courses recognised for professional registration are provided by the professional bodies and are assessed almost exclusively by output standard through national final examinations.

There are four levels to the academic base, each notionally a year of study:

Stage 1	Intermediate	–	AAT Certificate
Stage 2	Technician	–	AAT Membership
Stage 3	Professional	–	Professional Accountancy Certificate
Stage 4	Advanced	–	Chartered status

There are two pathways available: (1) Public Practice and (2) Commercial. However the examinations are the same for each pathway. Most entrants with a degree gain exemption from stages 1 and 2.

The assessment for the Professional stage consists of six examination papers which can be undertaken before entering a training contract. There are three sittings of the professional stage examinations each year.

The aim of the advanced stage is to integrate professional skills with business issues. The assessment consists of a rigorous Advanced Case Study (ACS) which consists of an examination of four hours duration, together with a Test of Advanced Technical Competence (TATC) which consists of two papers of 3.5 hours duration.

The ACS cannot be undertaken until the final year of the training contract and there are two sittings of the Advanced stage examinations each year.

The educational base of the accountancy profession is assessed almost exclusively by output standard through the medium of national examinations. The authorisation of training providers and the validation of curriculum provides a small measure of input standards. The educational base is linked to authorised training contracts which are available in approximately 2200 offices in the UK.

In the recently introduced new ICAEW qualification the professional stage syllabuses are written in full learning outcome format and have introduced a small element of objective testing into some examinations.

Whilst a numerate profession the skill appears to be viewed as artistic as well as scientific and, from a curriculum coverage point of view, the sole use of examinations as the means of assessment would be a cause for concern.