House of Lords Science and Technology Sub-Committee I Inquiry on Higher Education in STEM Subjects

Response on behalf of the Engineering Professors' Council

Introduction and Summary

The Engineering Professors' Council (EPC) provides a forum for senior academics responsible for engineering teaching and research in higher education. It has over 1600 members and represents virtually all of the universities in the UK, which offer degrees in engineering.

The subject matter of the current Inquiry is therefore of vital interest to our members, with whom we have consulted in preparing our response. Where our members have expressed diverse views, we have reflected these as they illustrate the complexity of many of the questions addressed.

While answers to the wide-ranging questions asked by the Committee do not lend themselves to being summarized, the following are among the key points made in this response:

- There are widespread concerns about 16-18 supply, both in terms of "hard science" and maths knowledge, and in standard of English together with work attitude and maturity;
- On graduate supply, the EPC is currently involved in research into engineering graduate employment with a view to elucidating the apparent mismatch between industry demand and graduate employment statistics;
- The EPC is concerned that, among other negative consequences, the recent higher education reforms will discourage potential students from taking longer undergraduate courses like the MEng, and from postgraduate studies;
- We see support for Master's qualifications as essential, particularly for subjects of national importance such as engineering;
- We are already concerned at the relatively small numbers of UK (as opposed to overseas) students taking MScs and doctorates in engineering, and would welcome measures to encourage take-up.
- Many of our members see the combination of teaching and research as crucial to a university education.

1. General questions

1.1. What is the definition of a STEM subject, and a STEM job?

***1.2. Do we u*nderstand demand for STEM graduates and how this could be used to influence supply?**

1.a) Almost any job that requires a numerate education is open to STEM graduates. Therefore the importance of STEM subjects to the economy is much wider than most commentators think.

1.b) One area that needs to be addressed in assessing this issue is that a substantial demand will come from SMEs, and it is not obvious how this can be quantified with any precision, since many are too over-stretched to respond to questionnaires. So the tendency will be to underestimate demand.

2. 16-18 supply

2.1 Are schools and colleges supplying the right numbers of STEM students and do they have the right skills to study STEM first degrees?

2.1.a) Our members have a number of concerns in this regard:

- There has been a fall in the ability to do 'hard science', and particular concern that the ability of those leaving school with high-grade maths A-levels is not enough for beginning on many engineering courses. To compensate, most universities have re-organised their first year maths teaching to compensate for the varying maths skills even for A & A* students.

- There is also significant concern that the risk-averse attitudes to practical/experimental work in schools directly and seriously undermines the quality of the preparation provided. Undergraduates are now starting from a lower base in terms of laboratory skills and practical awareness for engineering and science subjects than was previously the case. This inevitably affects what can be achieved at University and has a direct impact on our engineering and manufacturing industry.

- Concerns have also been expressed about the general attitude to, and aptitude for, a high standard of spoken and written English, as well as work-ethic and maturity. It is very important for engineers that they can articulate their ideas effectively.

2.2. What have been the effects of earlier government initiatives on the uptake of STEM subjects at advanced level?

2.2.a) There has been some improvement, leading to more applications overall.

2.3. What effect, if any, will the English Baccalaureate have on the study of STEM subjects in higher education?

2.3.a) We welcome the inclusion of a science as one of the qualifying subjects for the English baccalaureate. As a nation an increased emphasis on high attainment in English and Maths will also aid the study of, and achievement in, STEM in HE. However, exclusion of Design and Technology causes concern as this subject presents the only opportunity in most schools for the pupils to engage with creative practical work, which might excite their enthusiasm for engineering.

3. Graduate supply

3.1. Is the current number of STEM students and graduates (from the UK, EU and overseas) sufficient to meet the needs of industry, the research base, and other sectors not directly connected with STEM?

3.1.a) The National HESTEM Programme Midlands Region Hub (funded by HEFCE) is currently running a project led by our President, Professor Helen Atkinson FREng, on the employability of engineering graduates. This was prompted by the fact that some engineering graduates are unemployed despite the fact that a number of engineering employers say they cannot recruit enough engineers for their needs. The project is exploring the origin of the mismatch. There are a number of questions, for example: Are engineers graduating in branches of engineering where the demand is currently low (e.g. civil engineers for a construction sector currently going through a difficult time)? Are some graduates (for example for family reasons) wanting to live in parts of the country where there are not many engineering jobs? Are some engineers graduating without the skills and competencies engineering employers are looking for? Is there a correlation between being unemployed on graduation and degree class? The project is carrying out interviews with a series of engineering employers and also with unemployed and employed engineering graduates. The report is in the draft stage but contains much information of relevance to the House of Lords Inquiry. We would be delighted to pass on a copy of the report if the Inquiry would find it helpful.

3.1.b) Another aspect is that the question presupposes that industry has a requirement for STEM graduates that is knowable and predictable. For example, STEM graduates going into some industries may lead to greater a requirement for them - the system can be one of positive feedback because, within limits, growth in activity in the area increases demand for yet more graduates. This can lead to an (probably rather significant) underestimate.

3.1.c) In addition, we are not a command and control economy or political system. Therefore some people will train as engineers and then chose to go into other professions (indeed we would hope some would become MPs). That is healthy for society. It is therefore necessary to educuate more engineers than we actually need because there will always be leakage. It is also clear that graduates with engineering and other STEM qualifications are attractive to employers across the labour market because of the analytical and other non-technical skills they develop.

3.1.d) It is evident from data on MSc course entrants in autumn 2011, and initial figures for undergraduate applications for 2012, that supply has been damaged by the effects of Border Agency restrictions on potential overseas students and researchers. This has wider implications for engineering departments, which have a variety of income streams; if any one of these, such as overseas student fee income, is threatened, the capability to run the core undergraduate provision for home students is undermined because engineering is inherently relatively expensive to teach. Engineering students must develop an appreciation of engineering principles through laboratories and expertise in design through group design projects, which require intensive support. Almost all engineering departments in the UK would be running at a loss if it were not for overseas students' fees. (The EPC with the Engineering and Technology Board (ETB) found in a detailed study published in 2007 that the sector mean Subject-FACTS cost for 2005/6 for a HEFCE4-fundable student in engineering was £6,9675 pa – compared to a HEFCE standard unit of resource for engineering of £6,134. To raise the current standard unit just to meet the mean would have required a 14% increase in the HEFCE funding allowance; relative costs have not significantly altered since (see Report on The Costs of Teaching Engineering Degrees[1]).

3.2. Is the quality of STEM graduates emerging from higher education sufficiently high, and if not, why not?

3.2.a) The majority of engineering degrees are accredited by the Engineering Council, and so are quality- assured. However, within that framework, our members believe the quality to be variable. Engineering is a highly demanding subject, which requires competence in engineering science, communication and practical abilities. Due to financial and time restrictions, universities have reduced the amount of hands-on activities that the students undertake. The variation in quality also reflects the starting point for some students and access to high quality teaching and research facilities.

3.2.b) A specific concern that has been expressed is about over-reliance, often for financial reasons, on computer simulation rather than hands-on practical experience.

[1] http://www.epc.ac.uk/uploads/occasional_papers/FINAL%20ETB-EPC%20Study%20Summary.pdf

3.2.c) UK-based undergraduates need to understand that to make themselves employable in a highly competitive job market they must demonstrate through the application and interview process the highest standards of aptitude, achievement and motivation.

3.3. Do STEM graduates have the right skills for their next career move, be it research, industry or more broadly within the economy?

3.3.a) Again, the majority of engineering degrees are accredited by the Engineering Council, and so are relevant to the engineering profession. Many university engineering departments use their close links with industry / employers to ensure that their courses are relevant to demand, though in some cases there may be scope to develop this further; however, a balance has to be struck since different employers look for different things, and the SME sector – a major employer of engineering graduates – has widely differing requirements from those of larger-scale Industry. In addition, university education cannot replace specific training that industries require (and often look for when making job appointments) – industries will inevitably need to train staff for their business needs. Specific evidence on what employers want more of is contained in the IET's Engineering and Technology Skills & Demand in Industry Annual Review 2011[2]

3.3.b) A related issue concerns the balance in course content between "hard" engineering skills and "soft" skills such as management, sustainability, health and safety etc; while some see the latter as important, others feel that the curriculum is too slanted in this direction, to the extent of pushing out even from four-year MEng courses technical content that was previously included in their three-year BEng forerunners.

3.4. What effect will higher education reforms have on the quality of teaching, the quality of degrees and the supply of STEM courses in higher education institutions?

3.4.a) While it is too early to know, EPC members have expressed the following concerns:

- Increased competition for students may open rivalry between academic providers for students, with potential adverse effects on provision of high quality teaching.
- It is difficult to see how good quality engineering degrees could be provided by low-cost providers.
- Higher fees will raise student expectations and demands, and may choke off numbers from disadvantaged backgrounds.
- There are widespread fears that university funding will not increase in real terms, hence it is unlikely the increased service expected by students will materialise. In parallel to this, research activities will be streamlined, which will impact on teaching our students the leading-edge activities as well as core engineering.
- It will be important to ensure that funds provided for SIVs and STEM initiatives are not used for other purposes. STEM subjects generally need more funding than many others – despite typical student fees being the same for all subjects.

3.5. What effect does "research assessment" have upon the ability to develop new and cross-disciplinary STEM degrees?

3.5.a) While some of our members consider it to have In principle a positive impact, there is a perceived danger that research is "bent" to fit specific funding, and results "bent" to fit assessment schemes, rather than pursuing and reporting what is scientifically or technically optimum. This can reduce the disciplinary spread.

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[2] http://www.theiet.org/factfiles/education/skills2011-page.c fm

3.5.b) There is also widespread concern that engineering academics generally have less engineering experience than a generation ago. Many come straight through a university route and many are more science/maths than engineering-based. This is likely to be exacerbated by RAE/REF initiatives. Recruitment of mature engineers from industry is virtually precluded as they generally cannot display enough peer-reviewed research publications, or grant awards.

3.5.c) In addition, the REF and similar activities have actually reduced the number of 'teaching academics' as well as those with industrial experience. For academics to be successful, they are measured on their research, and this inhibits the design of new courses due to the time required. It also ensures that teaching is often not seen by the new career academics as the core of their academic activities.

3.6 What is the relationship between teaching and research? Is it necessary for all universities to teach undergraduates and post graduates and conduct research? What other delivery model should be considered?

3.6.a) Many of our members see the combination of teaching and research as crucial to a university education, as opposed to further education, as it allows universities to update course content continually with new material related to current research activity. This refreshes and enlivens teaching. In addition, research in collaboration with industry contributes to teaching that keeps track with industry's requirements for appropriately qualified graduates. It is also an aspect of our world-class university system that helps to attract overseas students.

3.6.b) The model of university PhD students contributing to research projects (be they university, industry, national lab, or a combination) is a model that works already, and should not be put at risk. For undergraduate students, the combined teaching / research system can excite them with the thought that a profitable role exists in research and/or industry. The best way to stimulate them in this direction is to allow them to contribute through their undergraduate projects to live research projects, and preferable, ones engaged with industry. This effectively ties the whole system in to one coherent philosophy.

3.6.c) While it might be possible to have a dual track system, or if research funding was restricted to only a few universities, staff mobility between the two streams would be difficult and the 'technical stream' might become de-motivated. The intellectual quality of teaching across the sector would be undermined, as would the international reputation of our teaching.

3.7. Does the UK have a sufficient geographical spread of higher education institutions offering STEM courses?

3.7.a) Yes at present, though with higher costs, more students may need to study from home, hence limiting choice in the range of courses available locally. The needs of mature and part time students also need to be taken into consideration, and will become more important as demographic changes bite.

3.8. What is being done and what ought to be done to increase the diversity of STEM graduates in terms of gender, ethnic origin and socio-economic background?

3.8.a) The EPC has supported and participated in various initiatives to address these issues. Bursaries, which are being offered by most if not all universities, are clearly important. However, selection at all levels should be dependent on set criteria related to ability and qualifications, not positive discrimination.

4. Post-graduate supply

4.1. Is the current training of PhD students sensitive to the range of careers they subsequently undertake?

4.1.a) Some of our members would see this as the wrong question, and note that a PhD is a journey of scientific discovery; some training along the way may be helpful but it is not the main point. Some PhDs (in physics, for example) end up in something completely different, like tourism. It is not the role of the university to dilute training by catering for this explicitly. However, the core function of a PhD is 'training in methods of research'. It should be the case that an understanding of the methodology of research could be applied by the student in disparate areas.

4.1.b) On the other hand, a much higher percentage of engineering PhDs find employment more specifically linked to their respective PhDs than in many other subjects, indicating that PhD training is sensitive to their careers. While pure science PhDs are entered upon with the full knowledge and expectation that any employment opportunities will rely more on the merits of the individual CV rather than the specific subject of the PhD, PhD studies in applied sciences can be more focussed towards technology and enterprise applications.

4.1.c) We also note that there has been a significant broadening of the training of doctoral students (PhD, EngD and Industrial Doctorates) in recent years as a result of Sir Gareth Roberts' report. Most engineering departments are addressing this agenda. The developments have given more consistent provision and encouraged engineering PhD students to interact more with other disciplines. It has also given greater credence to training activities in industrial sector partners where this happens. This helps to foster interdisciplinary thinking as well as broadening career horizons. There is some concern that where the PhD provision is small research students may not be getting this benefit, so some would support greater concentration of doctoral training or encouragement of networking between geographically convenient institutions, particularly for formal training.

4.2. Are we currently supporting the right number of PhD studentships to maintain the research base and are they of sufficient quality?

4.2.a) Even within our membership, there are differing views on this. While in some areas the system seems roughly in balance, many of our members see that the numbers are too low, and that the burden of debt from pre-PhD studies will discourage many home students who would otherwise have done a PhD.

4.2.b) Employers do recognise the strength of the doctoral training and the strong and sophisticated skills that they have gained. The take up of PhD and Industrial Doctorate (previously EngD) graduates by industry is therefore very strong, into both research and non-research careers. As a result, the number of PhD graduates is not adequate to maintain the research base, either in academia or in industry. This is evidenced by the very large number of posts that are filled by non-UK (often non-EU) nationals.

4.2.c) A further aspect is that, in the view of some, an expansion of the PhD student numbers would enhance the research base, and deliver good engineering science at lower cost, but frequently no less effectively, than provided by a more senior research associate. We see the decision of EPSRC to disallow the inclusion of the cost of PhD studentships on grants as therefore particularly unhelpful in this respect.

4.2.d) As regards quality, some of our members see ever decreasing number of home student applications relative to those of overseas students as a key issue, particularly because of language challenges at this level, especially with students coming from countries where English is not taught and or spoken as mother tongue or as the first foreign language.   To increase home student applications to PhD studies, a helpful approach would be to boost industrial support with more national schemes with specific titles/ areas of research. On occasions and places where this is done effectively, there have been significant increases of home student applications.

4.2.e) There is, however, a risk as perceived by some members that PhD students are being oriented too strongly to short term, low scientific quality, industrially defined projects and lack the stimulus towards creative and innovative longer-term research activity. This could have longer-term impacts for our engineering skills in the future.

4.3. What impact have Doctoral Training Centres had on the quality and number of PhD students? Are there alternative delivery models?

4.3.a) Most of our members consider the DTC model to have had a very positive impact. It permits better training opportunities because of larger numbers, more risk-taking by doctoral students in the projects that they undertake and in the way they do their projects (although this also depends on the flexibility given by their supervisors), and encourages less isolated experience. The move away from project studentships is welcomed by some, as these were often much too prescriptive and did not allow students to develop as independent researchers. Interdisciplinary groupings allow students to pursue their research ideas with a variety of stimuli.

4.3.b) The impact has also been positive both in terms of quality standards and also in terms of student numbers including home-based student numbers. One suggestion is that these could be further enhanced with the formal establishment of more "Graduate Schools in Science and Engineering" and also with specific titles such as "Graduate School of Bio-Engineering", "Graduate School of Information Technologies", etc. Some consider that the separation of undergraduate from post-graduate teaching and supervision could be more formalised with much more clear demarcation of academic staff specifically to either undergraduate or postgraduate teaching and project supervision, although this is not a universally held view.

4.3.c) On the other hand, some observe that the structure of the competition for DTCs has meant individual projects that might attract a good student are constrained by the subject areas of DTCs. This has a negative impact, especially as the DTCs are restricted to specific areas and hence reduce the opportunity for new and novel research areas that fall outside of the DTC subject areas .It appears that is going to be far harder to have a diverse range of subjects covered.

4.3.d) There are high quality PhDs in universities which do not have Doctoral Training Centres, including PhDs are in collaboration with industry e.g. through CASE studentships. The establishment by many universities of Graduate Schools has significantly improved the base of skills and wider interaction that students are gaining through their PhD.

Therefore we would see advantage in having several models working side by side, to give flexibility and the best capture of excellent candidates. DTCs fit within this, but should not be the only model.

4.4. Should state funding be used to promote Master's degrees and is the balance right between the number of Master's degree students and PhD students?

4.4.a) Again, our member have a range of views, although they are united in agreement that state funding should be used to promote – and directly support – Master's degrees – though this should in no way detract from support for PhDs (see response above to 4.2).

4.4.b) For eventual professional qualification as a Chartered Engineer, a Master's degree accredited by one or more of the professional engineering institutions is a requirement; this is gained at present either through a four year integrated Master's, or following a BEng with an MSc (or equivalent further learning) to satisfy the Engineering Council for registration. We are concerned that students will be deterred from taking the four year MEng course purely on financial grounds; or be deterred from following a BEng with an MSc, which would need to be privately funded on top of the accumulated student debt. For these reasons, we see support for Master's qualifications as essential particularly for subjects of national importance such as engineering.

4.4.c) One aspect of this is that already our 'hard-science', world leading, MSc courses, many of direct industrial relevance, are now almost free of UK participants, because those who would be qualified to take them can take well paid careers (often in finance, or even non-specialist engineering) without undertaking expensive and difficult training to add to their student debts.

4.4.d) There is a view that establishment and recognition of Graduate Schools would address these questions in more detail and more effectively. State funding could be made available for the establishment of Graduate Schools, which could offer full-time, part-time, and life-long education and professional training courses in collaboration with specific industry sectors. This would also ensure that we continue to nurture talent and develop expertise for research whilst promoting more young employment opportunities.

4.5. What impact will higher education reforms have on the willingness of graduates to pursue a research career?

4.5.a) There is widespread agreement among our members that tuition fees will have a negative impact, when set against other costs that young people face, such as buying a house etc.

4.5.b) Particularly in engineering where jobs are plentiful many will choose to take a job even if they may have preferred to pursue research. The stipend needs to keep pace and there needs to be some way of alleviating the long term burden of the loans that they have accrued. This would be an incentive to pursue research. In many other fields the need for differentiation in the market place will keep research student numbers up but this does not apply to engineering.

5. Industry

5.1. What incentives should industry offer to STEM graduates in order to attract them?

5.1.a) There is a range of possible options, including a high-pay, fast-track, scheme for really able people plus support for those who wish to undertake specialist training (MSc etc); help with loan repayments; placements, short and long term; and, within industry, training, improved career paths and salaries.

5.1.b) Any exposure to the commercial world during a degree course at any level is good and may encourage a student to move into a relevant STEM industry. However, this is not likely to happen more without some financial support. At undergraduate level, financial incentives (such as, but not exclusively, Higher Apprenticeships at Level 6) would encourage industry to take placement students (this would assist all sizes of industry). Industry would at the same time have the opportunity to 'sell' what it does to the undergraduate – catching them early.

5.1.c) CASE awards offer a win-win for the postgraduate students, industry and academia, offering minimal costs with maximum benefit in terms of giving students exposure to 'real' engineering challenges.

5.1.d) However, formal schemes for doing this (DTC/CASE) tend to involve long-term (years) commitment from companies involved, and hence are essentially limited to established industry. In some circumstances the situation would be improved by provision in both the funding mechanisms and degree requirements for research students to move in and out of a relevant start-up company quickly and easily – say for 1-6 months – for example to deliver small specific development projects. Critical timescales for a small company are often very short, and there is no easy way of doing this at present. It could encourage more PhDs to stay in the STEM commercial sector.

5.1.e) On one view, UK industry needs state incentives to attract and maintain research scientists and engineers in key export technology and novel application areas. Guidance could be provided to specific industry sectors how they may pursue schemes, which will enhance their export capabilities. The UK needs to establish new leads in export technologies and products.

5.2. What steps are industry and universities taking together to ensure that demand for STEM graduates matches supply in terms of numbers, skills and quality of graduates?

5.2.a) Industry and universities are working together in terms of visiting professorships, industrial advisory boards, joint research and CPD courses. However, there is not always an integrated vision on the way forward, often due to time and resource demands.

5.2.b) As indicated above (para 3.3.a), courses reflect generalized industry demand as regards content; numbers depend to a large extent on student choice/demand, which at the time of application may well not match industry demand four years or more down the line. The core output should be capable graduates who can work within a range of STEM areas.

5.2.c) Some of our members feel strongly that this question relates again to the quality of the people coming out of the schools system, especially as regards to practical and experimental skills, work ethic and maturity.

6. International comparisons

6.1. What lessons can be learnt from the provision of higher education in STEM subjects in other countries? Which countries provide the most helpful examples of best practice?

6.1.a) Many other countries have aspects of good practice that merit examination (and much good practice is also exchanged through collaborative research programmes and other links). Among countries that our members have mentioned specifically are:

- Finland (a dynamic engineering and research base),
- France (generous support terms for their top 'Grande Ecole' technocrats, along with good wages in industry);
- USA and Japan (Graduate Schools); and the Far East (higher education more geared towards the requirements of industry).

6.1.b) Graduate Schools are used most effectively in the United States and in Japan. Most engineering graduates from France and Germany effectively spend the fifth year of the Master's programme in industry, thereby providing industry with engineering graduates with the relevant industrial experience.

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16th December 2011

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