The Royal Academy of Engineering

UK Focus for
Biomedical Engineering

Policy paper

First Degrees in Medical Engineering: a positive step for engineering?

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This paper has been prepared by Professor Elizabeth Tanner FREng for the The Royal Academy of Engineering, the UK Focus for Biomedical Engineering and the Association of Institutions concerned with Medical Engineering (AIME).

Contents

Appendices

1. Rationale for the report

Both the UK Focus for Biomedical Engineering, hosted by The Royal Academy of Engineering, and the Association of Institutions concerned with Medical Engineering (AIME) have been concerned with the development of degrees in Medical Engineering. Many students are interested in Medical Engineering but have limited guidance in their degree choice. As these degrees are multidisciplinary, the balance between the engineering and the medical components of the degree varies among the different programmes in the UK. However, if the ratio is made appropriate, it will lead to graduates who have strong engineering skills combined with an understanding of the specific demands of working in the medical field. Furthermore, Medical Engineering is an expanding field with estimates of growth ranging up to 15% per annum. With people living longer and expecting a higher quality of life the demands for medical engineering devices and assistive technology equipment will increase. The UK leads in terms of the engineering science of many of the new techniques affecting clinical practice and, to some extent, in the industrial development of these techniques. If the UK is to continue to be world-leading it must ensure that graduates in Medical Engineering are trained to be able to continue this growth. Medical device, medical implant and equipment manufacture is generally a small scale, high value-added industry, thus the highly trained graduates completing such degrees will be working in a type of manufacturing environment for which the UK is very suitable. However, it should be noted that, at the moment, the UK manufacturing base in this area is low in spite of the appropriateness to UK plc and the high UK research activity in the area of Medical Engineering.

To quote Lord Sainsbury of Turville in the introduction to the UK Standard for Professional Engineering Competence (UK-SPEC) "The UK economy depends on improved business performance, which in turn relies to a great extent on the competence of our engineers and technicians. The UK has a proud engineering heritage, but in an increasingly competitive world our engineering competence must reflect the needs of business and industry for astute and experienced creators and managers of technology"[1]. This statement may have been written in relation to engineering competence in general, but equally applies to Medical Engineering. The aim of this report is to examine the current position with regards to the growing number of medical engineering degrees, how well they educate and train students and support the future employers of medical engineering graduates.

Following a proposal for this report, The Royal Academy of Engineering hosted a half day meeting on 19 October 2004. Presentations were given on various aspects of medical engineering degrees and followed by a wide ranging debate. This report incorporates the outcome of that meeting including input from academics, clinicians and employers involved in Medical Engineering. It is hoped that anyone engaged in developing a new, or teaching a current, medical engineering degree will find this report of assistance.

[1] http://www.engc.org.uk/documents/CEng_IEng_Standard.pdf

2. Author[2]

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[2] I would like to thank various members of both AIME and the UK Focus for Biomedical Engineering for their input into this report, in particular Professor Anthony Unsworth FREng of the University of Durham.

3. Executive summary

The UK has led many developments in the field of Medical Engineering, from the design of the first clinically successful hip replacement by Charnley in the 1960s, to the development of computed tomography and magnetic resonance imaging. However, the training of medical engineers (in the broadest sense) has “happened” when engineers have developed an interest in Medical Engineering from chance encounters with clinicians, or when occasional individuals have obtained qualifications in both fields. Secondly, despite the drop in the number of applicants to engineering degrees prior to an upturn in 2004, the interest in medicine and medically related disciplines in the UK is high and many universities are developing medical engineering streams to their engineering degrees to retain student numbers and to satisfy student demands. However, the balance between the engineering and the medical components of their degrees is highly variable, with about half the courses accredited by one or more of the engineering institutions. If the UK wants to build on the enthusiasm and intellect of these students and graduates, and continue to be world leading in the field, then this current system needs further consideration.

4. Main recommendations

- When developing medical engineering degrees universities should be strongly encouraged to develop degrees with a view to accreditation.
- Only universities having a close relationship with a medical school and with staff active in biomedical engineering research should attempt to provide such degrees.
- Medical schools with accelerated postgraduate medical degrees should review what is being taught in the different medical engineering programmes with the aim of considering the relevance of such graduates to the intake into their accelerated medical programme.
- The Institute of Physics and Engineering in Medicine should consider accrediting undergraduate medical engineering degrees, particularly those based around a general engineering background (where appropriate, in conjunction with other professional engineering institutions).
- All engineering institutions should ensure that their Accreditation Committee includes at least one member with the expertise to accredit medical engineering degrees within their areas of practice.
- The Engineering and Technology Board[3] (ETB) should include Medical Engineering in their annual analysis of data on Engineering in the UK.

[3] www.etechb.co.uk

5. Medical engineering undergraduate degrees

This paper only considers undergraduate degrees in Medical Engineering. Taught Masters Courses such as, for example, those at the University of Strathclyde and Imperial College London and all MRes, PhD and EngD degrees have been deliberately excluded. Only BEng, MEng, BSc(Eng) and BSc degrees have therefore been considered. Biomedical Engineering and related engineering speciality areas such as biomaterials, medical electronics and tissue engineering have been included. Medical physics has not been considered although it is noted that many medical physicists are employed in medical engineering positions and that many medical engineers are working in medical physics departments.

Throughout this document the subject “Medical Engineering” should be read to include all its subsets such as biomaterials, biomechanical engineering, medical electronics as well as general biomedical engineering degrees.

A brief outline of the three types of undergraduate degree courses offered in England, Wales and Northern Ireland follows. (It should be noted that in Scotland where Scottish “Highers” are the usual entry level qualifications rather than ‘A’ Levels, their degrees are generally one year longer than the equivalent degrees in the rest of the UK.)

BSc(Eng) and BSc

These are three year engineering and science degrees which generally are not accredited by any of the Engineering Institutions for Chartered Engineer (CEng), although they may be accredited for Incorporated Engineer (IEng). Unless accredited for IEng, the academic profile of the student intake is not normally affected by the requirements of UK-SPEC nor need the degrees fulfil the requirements covering what is taught in an accredited degree.

BEng

These are three year degrees with, in some cases, the provision for an additional year in industry. They generally have requirements from Engineering Council^{UK} (EC^{UK}) [4] and the ETB to include an individual project and sufficient design and mathematical content to enable the graduate to work as a professional engineer (Chartered Engineer, CEng), subject to the addition of an approved Masters degree or equivalent further learning and professional development where graduates apply and develop the skills and knowledge gained during their academic training.

MEng

These are four year degrees, again with the potential for an additional year in industry. The fourth academic year is intended to increase either the depth or breadth of the student’s knowledge or a combination of both. General design and mathematical requirements are similar to a BEng and students are required to complete an individual as well as a group project. These degrees are considered to provide sufficient academic training for a graduate to obtain Chartered Engineer status with professional development as required for a BEng graduate, but without additional academic training.

It should be noted that these descriptions are currently correct, but may be altered in the future by implementation of the 1999 Bologna Agreement of the Rectors of

[4] www.engc.org.uk

European Universities and European Ministers of Education[5]. Furthermore, the Engineering Institutions are reviewing their rules for the accreditation of engineering degrees in light of UK-SPEC taking over from SARTOR 3.

6. Rationale for medical engineering degrees

The number of applicants to UK engineering degrees has been falling over the last ten years for reasons that have been extensively reviewed elsewhere. These include the view that the engineering industry in the UK is in decline, that engineering is "dirty" and that it is a vocational rather than an academic subject. However, drivers such as the ageing population and the greater expectation of the population regarding medical treatments, have made Medical Engineering a popular and necessary career choice. Life expectancy has increased by 20 years over the last century, and so has the number of many age related diseases; for example, 40% of people over 70 have osteoarthritis of the knee. It is estimated that a male born in 1990 in an established market economy has a life expectancy of 73.4 years, but with full health for only 67.4 years, a difference of 6 years[6]. During these years of poor health people need medical support that includes a component of biomedical engineering. The increasing demands for a better quality of life throughout the world and the increasing use of technology and engineering in medicine and dentistry necessitate that Medical Engineering must be a growing part of the professions allied to medicine. Students, as they leave school, only have a limited knowledge of what a specific degree course entails. They may well choose a degree for emotional reasons such as what they "think" a subject is like, rather than having an intellectual understanding of what the specific degree entails. Engineering degrees, in particular, have suffered significantly from this problem. Additionally, since the 1990s, applicants for medical schools have been required to include at least one non-clinical degree on their university application forms. A significant number of these students have good or excellent mathematical and physical science 'A' levels (or equivalent qualifications) and are thus well qualified to enter engineering degrees.

Medical engineering degrees can be divided into two basic groups. The first, and the more common in the UK, is the "biomedical" version of one of the mainstream engineering specialities such as mechanical or electronic engineering. What is common in the USA, and driven by the generous tranche of funding provided by the Whittaker Foundation, is the more generalist medical engineering degree covering electrical, mechanical and materials aspects of medical engineering. For students going into medicine as medical engineering graduates these more general degrees may be more appropriate. In mainland Europe, where undergraduate training is generally longer, general biomedical engineering degrees are again the common model of medical engineering degree. Finally, throughout the world the demand for people with multidisciplinary training who can build on the skills and expertise of two or more areas of science and engineering is growing as industry and employers realise the strengths that such people bring. Many areas of science and engineering are progressively getting more and more specialised with consequent lacunae of knowledge between them. Medical engineers are highly qualified to bridge these interdisciplinary gaps.

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[5] www.ntb.ch/SEFI/bolgnadec.html

[6] *The Burden of Musculoskeletal Conditions at the Start of the New Millennium*, WHO Technical Report No. 919, 2003.

7. Advantages to medical engineering students

Engineering degrees are generally viewed as academically "good" degrees, i.e. providing students with what are seen by employers as good transferable skills and rigorous training. Engineering graduates have one of the lowest rates of unemployment and highest graduation salaries. According to EC^{UK} and ETB analysis of 2001 graduates, 62% of engineering graduates and 57% of all graduates were in full time employment within 6 months of graduating and 45% of engineering graduates were in professional positions compared to 25% of all graduates. Furthermore, at 6 months post graduation, 51% of engineering graduates were on a "high" salary compared to 21% of all graduates[7].

Medical Engineering is an important and growing area of engineering, but medical engineering graduates need to have sufficient strength in engineering to be able to function effectively as a main stream engineer. Having completed their medical engineering degree, graduates may wish to either remain in Medical Engineering or transfer to one of the conventional branches of engineering. Medical engineering companies need people who are fully trained engineers conversant with all the skills of their area of engineering. For example, students studying medical electronics should be able to become electrical and electronic engineers; similarly, biomaterials graduates should be able to work as materials scientists and materials engineers. Thus, a requirement for medical engineering graduates is that they should be capable of becoming Chartered Engineers within their area of engineering. On the other hand, these graduates should also bring to employers additional skills including at least a knowledge of anatomy and physiology and the ability to communicate with clinicians. Depending on the area of engineering, certain specific clinical knowledge may be appropriate and in any event the ability of students to assimilate clinical information should be a requirement for their training.

A second group of potential medical engineering students is those wishing to study medicine in the longer term. If they wish to gain entry into medical school as graduates then Medical Engineering should provide them with a suitable background. Whilst having obtained a BEng or MEng degree prior to entering medicine may be thought to add significantly to their time as a student, it should be remembered that most medical students (and a growing number of dental students) also undertake an intercalated degree, which adds one year to their course. These degrees allow students to expand their knowledge outside the confines of the clinical training within the medical and dental degrees. Intercalated degrees also allow students a chance to complete an individual project and to perform research. These elements of training are part of all engineering degrees. Graduate entry to medical school is becoming more common and some schools, for example St. Bartholomew's and the Royal London School of Medicine and Dentistry, are producing graduate entry programmes which will allow students with an appropriate degree to undergo accelerated medical and dental degrees. Hence, a student doing a BEng/BSc(Eng) and a graduate entry accelerated MB BS degree would spend 3+4 (total 7) years, compared to a direct entry medical student who will take 6 years to graduate (including an intercalated year). At least one institution, Imperial College London, has recently developed dual entry degrees combining Medical Engineering and medicine. In this degree, after the common first two years, students have options of completing a 3 year BEng with subsequent graduate entry to the medical degree programme, or a 4 year MEng for students wishing to remain in engineering. Within the UK there are three medical engineering related intercalated degrees (Appendix IV), indicating the number of areas of medicine and dentistry where engineering knowledge and skills are

[7] EC^{UK} and ETB Digest of Engineering Statistics 2003/4, July 2004.

considered to be highly beneficial to clinicians. It should be noted that these degrees have been developed in the last few years. As medicine becomes more technology driven, the need for clinicians with a good engineering knowledge can only increase. Professor Brian Hopkinson has commented that "Currently, almost all the medical schools are trying to recruit graduates with first-class degrees from other disciplines as we find that these graduate students are far more dedicated to medicine than those who come in straight after 'A' levels. In fact, many of the great medical innovators that I know, such as Tom Fogarty in the States and Professor Angelini in Bristol, studied engineering before entering medicine and for them it has been a marvellous combination". Thus, in specific areas of medicine taking a medical engineering degree prior to entering medicine will become not merely an option, but a preferred route. The medicine-engineering dual qualified individual, already commonly seen in the US, will become more common in the UK. However, it should be noted that 'A' level chemistry is needed for some, if not all, of these graduate entry programmes. For students entering with mathematics and physics, but not chemistry, at 'A' level, consideration needs to be given to ensuring that they are given the opportunity to take 'A' level chemistry in parallel with their degree, whether inside or outside their university.

8. Accreditation of medical engineering degrees

As can be seen from Appendices II and III, the majority of medical engineering degrees are either accredited or aiming for accreditation. As far as graduates of these courses are concerned this will bring an international portability to their degree. CEng, IEng and EngTech portability are covered by the Washington, Sydney and Dublin accords, respectively. Here the signatories have agreed to recognise each other's accredited programmes. The countries currently covered by these accords are Australia, Canada, Hong Kong, Ireland, New Zealand, South Africa, UK and USA - with interest in joining being expressed by Japan, Korea, Malaysia and Germany[8]. These agreements are in addition to the agreements within the European Community. Given the financial and cultural benefits to departments of overseas students, the benefits of having their medical engineering degrees accredited are substantial. Overseas students are more likely to apply for accredited than non-accredited degrees. The European Commission has funded the ESOEPE programme to develop a framework for accrediting engineering education throughout the EU, with a steering committee comprising members from France, Germany, Ireland, Italy, Portugal, Russia and the UK.

The European Alliance for Medical and Biomedical Engineering and Science (EAMBES) is also considering the accreditation and portability of medical engineering degrees throughout Europe. It arranged three meetings in Europe between December 2004 and July 2005 which also fed into the meeting of the Whitaker Foundation[9] in March 2005. The aims of the EAMBES meeting included "help universities design and modify biomedical engineering programmes to meet future needs". The objectives were "to develop and establish consensus on European guidelines for the harmonization of high quality MBES programmes, their accreditation and for certification and continuing education of professionals working in the health care systems". The benefits to the UK, given the necessity for most of these graduates to be able to use English as their working language, are potentially substantial. The first meeting in Eindhoven in December 2004 considered the range of subjects that should be covered. Consideration was given to the balance between

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[8] Presentation by Professor Ian Freeston, at the Royal Academy of Engineering Meeting, 19th October 2004

[9] www.whitaker.org

the medicine based subjects and engineering areas. The UK concerns over balancing the breadth of the subject that can be covered in a degree with the depth of any particular stream within the subject did not arise. Virtually all the universities concerned were involved in general engineering degrees. The continental European universities were not concerned about the depth versus breadth balance because there engineering has always been taught at the five year masters level - usual for engineering degrees in mainland Europe. They have now moved or are moving to the 3+2 (bachelor + master) model required by the Bologna agreement[5]. Most assume that students who are going on to work as medical engineers will undertake a full five year degree programme.

The previously constraining input requirements of SARTOR 3 have been substantially relaxed with the development of UK-SPEC[10] (which replaces SARTOR 3) with the increased emphasis on outcomes rather than input qualifications. These outcomes are defined in terms of *general learning outcomes*, such as knowledge and understanding, intellectual abilities and specific learning outcomes, including the underpinning science and engineering, design and engineering practice. For medical engineering degrees, consideration needs to be given to the "essential facts, theories and principles" required. It is apparent that the medical content of a medical engineering degree cannot be comprehensive, therefore, choice of illustrative examples is essential, although these need to be supplemented with relevant directed reading. Consideration of the requirements of accreditation may well make developing accredited medical engineering degrees challenging, but also worthwhile. The requirements for both engineering accreditation and medical input make these degrees intellectually and academically highly challenging. They cannot be considered to be lightweight or "soft" degrees by students, universities and the engineering institutions and may be more challenging than many mainstream engineering degrees.

9. Concerns for medical engineering students

The concerns of students undertaking medical engineering degrees can be summarised as: whether they will gain sufficient knowledge of "**engineering**" to be effective engineers and whether they can obtain enough knowledge of "**medical**" topics to feel that they are gaining the sufficient exposure to clinical expertise. In many ways the first of these considerations will be answered if students complete an accredited degree, since, by definition, the course will require appropriate output standards in engineering knowledge and other numerate subjects as required by UK-SPEC[10]. For example, in the case of the Institution of Engineering and Technology (IET), the requirement for accreditation is that 70% of the degree should be technical (engineering)[11]. Of the engineering institutions that are members of AIME (Appendix I) and that also accredit CEng/IEng engineering degrees, two (IET and IoM[3]) currently have a medical engineer on their accreditation committee. Degrees within Medical Engineering (Appendices II and III) are in the areas of general engineering, electrical and electronic engineering, materials science and metallurgy, and mechanical engineering. Currently, there is no obvious body to accredit general medical engineering degrees. However, there is probably strength in having medical engineering degrees dual accredited, as currently occurs with mechanical engineering and materials accredited by IMechE and IoM[3]. The Institution of Physics and Engineering in Medicine (IPEM) does accredit MSc degrees in Medical

[10] UK Standard for Professional Engineering Competence: Chartered Engineer and Incorporated Engineer Standard, published by Engineering Council UK.
[11] Communication from IET.

Engineering and it would seem appropriate that they should consider the accreditation of both specific and general medical engineering degrees, either alone or in parallel with one or more of the other engineering institutions. It should be noted that all the engineering institutions that would be involved in such dual accreditation are members of AIME (Appendix I).

In the US, a substantial number of general medical engineering degrees have been developed under the auspices of the Whitaker Foundation, which has also provided funding. In the US, between 1979 and 2002, the total entry to engineering degrees has fluctuated between 330,000 and 410,000. Since the start of Whitaker Foundation funding in 1991 the medical engineering intake rose from 2,000-4,000 per year to nearly 11,000 in 2002[12]. Whereas in the UK "general" medical engineering degrees are few, in the US all medical schools are graduate entry so general degrees as "pre-med" are highly popular. Students going on to research degrees or into industry will normally read for a Master's degree (where they can gain the depth of knowledge expected of engineering graduates in the UK). In terms of future activity, American biomedical engineering graduates can be divided into one third going to medical school, one third staying on at university to study for a Master's degree and one third going into industry. However, it should be noted that many of the students going directly into industry are involved in the marketing and sales end of the medical engineering industry.

Given the breadth of knowledge required for a general engineering degree and the additional requirement for familiarity with medical subjects, in a general medical engineering degree it does seem unlikely that sufficient engineering depth and breadth can be gained in a three year BEng degree. The conclusion is that general medical engineering degrees should be four year MEng degrees, unless they are seen as solely "pre-med" programmes. Organisers of such general medical engineering degrees in the UK need to consider the dichotomy of depth versus breadth. If they opt for a broad general medical engineering BEng degree programme they should consider whether there are enough places in postgraduate medical schools for all their graduates. Additionally, it is also important to ask whether their graduates will have sufficient engineering knowledge and skills to be able to function as engineers.

The appropriate academic mix between medical and engineering modules[13] also needs appropriate consideration. Students apply for a degree with a medical engineering title because they wish to study a reasonable number of medically related modules. Insufficient units will demotivate students so that they will either leave or fail to benefit fully from their degree. Furthermore, employers of medical engineers expect these graduates to understand the application and context of medicine within engineering to be useful. What these modules actually contain will depend on the specific area of Medical Engineering the students are actually studying, but should include anatomy and physiology to a reasonable level.

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[12] Presentation by Professor John Lever at the Royal Academy of Engineering Meeting, 19th October 2004.

[13] Modules should be taken to mean the individual lecture courses attended by students during their degree.

10. Potential solutions to concerns of medical engineering students

All engineering degrees require students to gain knowledge of the fundamentals of engineering science. Over the years specific examples have been developed and used to demonstrate or illustrate these engineering principles. In most engineering departments such examples are related to non medical applications, but there is no reason why these examples cannot be medically related. In many of the modules students reading medical engineering will be taught alongside students reading for "conventional" engineering degrees, thus the requirement for these engineering principles to be relevant and stimulating to both groups of students is important. For students on non medical engineering degrees, examples from the medicine field are normally stimulating and expand their view of the applications of engineering science in the "real world" thereby broadening their minds and ideas. In design courses, the principles of engineering design are identical for a motor car or a kidney dialysis machine, although the application is different. When students are divided into groups for design studies, the medical engineering groups can focus on problems relevant to their speciality so when projects are presented to "conventional" engineering students these will be able to benefit from the consideration of solutions within a different set of design constraints. Institutions with intercalating medical students can further benefit from the clinical input of these students into the design project groups. Individual and group projects again will be specific for Medical Engineering, but the concepts of experimental design, methodology, data analysis etc., which are fundamental to engineering projects, will remain. In universities with strong connections to medical schools there are substantial advantages in securing clinicians to present problems for biomedical engineering students to solve, thus ensuring that students are well aware of the clinical relevance of their work. Furthermore, the solutions have the potential to be clinically useful and may even affect clinical practice.

11. Advantages to universities, engineering employers and the engineering institutions

Some students only wish to study Medical Engineering, but not other branches of engineering. In most cases this is part of the general misconception of what "engineering" actually involves. In addition, Medical Engineering is generally perceived as more "people friendly" than many other branches of engineering. For example, when 12 year olds were asked about professions they might join, over half were "not interested in engineering". However, when asked if they would like to develop medical equipment less than 25% were "not interested"[14]. Although the trend was reversed in 2003, the number of applications to engineering degrees in the UK has decreased annually since 1992. However, UK plc must produce more engineering graduates to meet the demands of industry. By bringing students into engineering via the medical engineering route, the number of good applicants to engineering should increase but the engineering institutions must play their part.

Provided there is sufficient depth of engineering content in the degree course, graduates can (and will) go into the non-medical areas of engineering. This route will therefore provide more engineering graduates and consequently lead to more

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[14] *The Effect of Brand Identity on Career Choice in the Engineering Profession*. Jane Armstrong MA Thesis 2003, University of Greenwich.

members of the engineering institutions and profession. Predicted drops in institution membership in the medium term have been identified by many professional institutions and they are keen to reverse the trend to ensure a highly skilled and professional engineering body. Medical Engineering will also provide graduates to other sectors that typically hire engineering graduates, for example the financial sector of the City and numerate professions such as accountancy. The increase in number of academically highly qualified students reading for engineering degrees can only benefit engineering and the engineering institutions, as well as improving the wealth of the nation. It is interesting to note in the 2003/4 EC^{UK} and ETB Review of Engineering Statistics that Medical Engineering under any variation is not mentioned once[15].

It should be noted by those concerned with gender balance that medical schools currently have in the region of 70% female students. Medical engineering degrees commonly have over 1/3 of their intake female and the number of women academics involved in teaching Medical Engineering may be estimated from the list of the participants to The Royal Academy of Engineering meeting in October 2004 (Appendix V).

12. Concerns for universities, engineering employers and the engineering institutions

There are two major questions that remain for both universities and the engineering institutions.

1) Will such students have sufficient initial **starting** knowledge to be able to undertake an engineering degree? If the intake includes students who have applied to, but did not get into, medical and dental schools their entry qualifications may well be higher than those of applicants to the main stream engineering degrees, even though in some cases their qualifications may not include ‘A’ level mathematics. However, universities have had to deal with the declining mathematical skills of the school leavers for the last decade or more[16]. Current activities to improve mathematics in schools, such as those suggested by Smith[17], will take time to feed through to incoming engineering undergraduates.

2) Will such students gain sufficient engineering knowledge **input** through their degrees?
This consideration will depend on how the curricula are devised and on the balance between the engineering and the medical modules throughout the degree. Accreditation of these degrees by appropriate engineering institutions will help to ensure that the graduates from these degree programmes gain high quality engineering knowledge and skills. In developing any engineering degree programme academics need to ensure rigorous and robust engineering programmes to equip students for whatever engineering or non-engineering career they follow post-graduation. This constraint applies equally in Medical Engineering.

All courses need to be led by academics whose research interests are in the field of Medical Engineering, thereby ensuring a strong applicability of the programme to research and clinical practice. In addition, the projects must be academically and clinically relevant. It is necessary to have strong, preferably clinical, input into the

[15] ECUK and ETB Digest of Engineering Statistics 2003/4, July 2004.
[16] Engineering Professors Conference, 2001.
[17] A.F.M. Smith, *Making Mathematics Count*, The Post 14 Mathematics Inquiry for Department for Education and Skills, 2004.

medical aspects of both the design of student projects and the teaching of modules within the degree. Unfortunately, this ideal is being further hampered by the change in Health Service priorities and the subsequent reduction in the requirements for clinicians to have been involved in research prior to becoming a consultant.

13. Employment of graduates in the medical engineering industry

The employment of graduates is a controversial area in the development of medical engineering degrees and needs to be considered in the light of the UK and world medical engineering industry. Medical engineering graduates go into a variety of jobs. The industry is bimodal in terms of company size: there are 221 member companies of the UK Association of British Healthcare Industry (ABHI) ranging from the household names, such as Johnson & Johnson with over 100,000 employees worldwide and Smith & Nephew with over 12,000 employees worldwide, to SMEs with as few as one or two employees[18]. The large companies will continue to employ specialists, such as mechanical or electronic engineers who have graduated with limited biomedical knowledge, but have depth in the engineering components of the projects. However, a growing number of SMEs need their employees to have a broad range of background knowledge for two different reasons. Firstly, due to their size, they are not able to employ a range of specialists. Secondly and more importantly, they are relying on turning novel ideas and concepts into devices and implants. Hence they need multidisciplinary people such as medical engineering graduates. Furthermore, with the number of start up companies being spun off from UK universities, the number of jobs should increase over the next few years. There are certainly not enough jobs for all the graduates from the medical engineering degrees currently being run in the UK. Also, due to lack of a UK manufacturing base, a significant number of the jobs available in the UK are in sales and marketing rather than research or production.

Graduates can obtain employment in the NHS, but entry to this route is heavily over subscribed. There are approximately 25 places annually on the NHS training scheme for medical engineering related graduates, 25 applicants per place being experienced on the IPEM accredited training positions[19]. It should be noted that currently this NHS graduate training scheme is under review and it appears likely that it will be devolved to universities. A significant percentage of graduates from other engineering specialities are not employed in engineering. These graduates are typically to be found in both the numerate professions such as banking and accountancy and non-numerate professions. Medical engineering graduates will also go into these fields. Their knowledge and training are seen as being extremely useful in areas such as venture capital funding, especially in the field of medical engineering companies. With the increasing number of medical engineering degrees it seems likely that medical engineering graduates will, as already occurs in the US, go into the sales and marketing area of healthcare, e.g. in the healthcare device industry. The increase in manipulation of biological data, which is the result of activities such as genomics and proteomics, is likely to lead to an increased demand for medical engineering graduates with expertise in medical informatics.

The other route for medical engineering graduates is to enter medical school via the graduate entry. Over the last ten years there has been a significant increase in the number of graduate places available within UK medical schools. Some medical schools offer relevant graduates entry to courses of 4 or even 3.5 years duration compared to the 5 years for a standard medical qualification. Dental schools are also

[18] http://www.abhi.org.uk/memberslist.asp
[19] Data from Mark Tooley on behalf of IPEM.

developing graduate entry programmes and these may well take materials or mechanical engineering based or medical engineering graduates. However, it is not clear whether all these graduate entry medical degree programmes are aware of the benefits of taking medical engineering graduates rather than the biomedical sciences and physiology graduates, which is currently the more common intake for graduate programmes.

14. Full Recommendations

When developing medical engineering degrees universities should be strongly encouraged to develop degrees that will potentially be accredited.

- Universities should be aware that some students will become professional engineers and thus need to have studied an accredited degree, while others will be using their degree to enter post graduate medical degrees.
- General medical engineering degrees should be 4year MEng if the graduates are expecting to work as engineers, while the general medical engineering 3 year BEng/BSc(Eng) degree may be suitable as a pre-clinical degree.

Only universities having a close relationship with a medical school and with staff active in biomedical engineering research should attempt to provide such degrees.

- Medical engineering degrees cannot function effectively without input from clinical and non-clinical staff of a medical school.
- Input from clinicians in terms of both teaching and in the development of clinically relevant projects is to be strongly encouraged.
- When using these degrees as entry to graduate medical programmes consideration needs to be given to ensuring that any other qualifications needed for medicine (such as 'A' level chemistry) are available to students who need to gain such additional qualifications.

Medical schools with accelerated postgraduate medical degrees should review what is being taught in the different medical engineering programmes with the aim of considering the relevance of such graduates to the intake into their accelerated medical programme.

- Medicine and dentistry needs to be aware that having engineering trained clinicians will only benefit their professions.

The Institute of Physics and Engineering in Medicine should consider accrediting undergraduate medical engineering degrees, particularly those based around a general engineering background (where appropriate, in conjunction with other professional engineering institutions).

- Where appropriate, combined accreditation visits in collaboration with other professional engineering institutions are encouraged.

All engineering institutions should ensure that their Accreditation Committee includes at least one member with the expertise to accredit medical engineering degrees within their areas of practice.

- Members of accreditation panels may experience difficulty in assessing the engineering content of a medical engineering degree unless at least one of their members has significant experience of Medical Engineering.

The ETB should include Medical Engineering in their annual analysis of data on Engineering in the UK.

Appendices

I Member Institutions of AIME

AIME Members	Accredit undergraduate engineering degrees?
Institution of Chemical Engineers (IChemE)	✓ but not Medical Engineering
Institute of Engineering and Technology (IET)	✓
Institute of Healthcare Engineering and Estate Management (IHEEM)	×
Institute of Materials, Minerals and Mining (IoM^3)	✓
Institution of Mechanical Engineers (IMechE)	✓
Institute of Physics (IoP)	Only CPhys accreditation
Institute of Physics and Engineering in Medicine (IPEM)	Currently only postgraduate masters not undergraduate degrees

These two lists were complied from 2007 degree start date UCAS website and do not include degrees of the Engineering with medical engineering type.

II Accredited and provisionally accredited medical engineering degrees

Divided by general area of the home department

<u>Engineering Science / General Engineering</u>

University of Birmingham
    Biomedical Engineering, BEng & MEng
University of Bradford
    Medical Engineering, BEng & MEng
University of Hull
    Mechanical and Medical Engineering, BEng & MEng
Imperial College London
    Biomedical Engineering, BEng & MEng
University of Surrey
    Medical Engineering, MEng

<u>Electrical and Electronic Engineering</u>

University of Liverpool
    Medical Electronics and Instrumentation, BEng & MEng
University of Sheffield
    Medical Systems Engineering, BEng & MEng

<u>Materials Science and Metallurgy</u>

Imperial College London
    Biomaterials and Tissue Engineering, MEng
University of Liverpool
    Biomaterials Science and Engineering, BEng
Queen Mary University of London
    Biomedical Materials Science and Engineering, BEng
    Materials Engineering in Medicine, MEng
    Dental Materials, BEng & MEng
University of Sheffield
    Biomaterials Science and Tissue Engineering, BEng & MEng
    Biomedical Engineering, BEng & MEng

<u>Mechanical Engineering</u>

University of Bath
    Medical Engineering, BEng & MEng
    Plus both of these with French or German
University of Birmingham
    Biomedical Engineering, BEng & MEng
Cardiff University
    Medical Engineering, BEng & MEng
Queen Mary University of London
    Medical Engineering, MEng

III Non-accredited medical engineering degrees

Divided by general area of the home department

Engineering Science / General Engineering / Combined Departments

University of Bradford
    Clinical Technology, BSc
City University
    Biomedical Engineering, BSc & BEng
University of Hull
    Medical Product Design, BSc(Eng)
Swansea University
    Medical Engineering, BEng & MEng starting 2007
University of Ulster
    Biomedical Engineering, BSc

Electrical and Electronic Engineering

University of Plymouth
    Medical Electronics, BSc

Materials Science and Metallurgy

University of Leeds
    Biomaterials, BSc
University of Nottingham
    Biomedical Materials Science, BSc
Queen Mary University of London
    Biomaterials, BSc

Mechanical Engineering

Queen Mary University of London
    Medical Engineering, BSc(Eng)

Non Engineering Departments

University of Birmingham (Dental School) - Biomedical Materials Science, BMedSc

Accredited by British Society of Prothetists and Orthotists

Strathclyde University - BSc in Prosthetics and Orthotics
Salford University - BSc in Prosthetics and Orthotics

IV Medical Engineering related Intercalated BSc Degrees for Medical / Dental Students

St Bartholomew's and The Royal London School of Medicine and Dentistry (QMUL)
Biomedical Engineering – offered by Department of Engineering, QMUL
Clinical Materials – offered by Department of Materials, QMUL University College London
Medical Physics and Bioengineering – offered by Department of Medical Physics and Bioengineering

Appendix V

Attendees: Degrees in Biomedical Engineering – a positive step for engineering?'
19th October 2004, The Royal Academy of Engineering, 29 Great Peter Street, London, SW1P 3LW

Chairs

Professor Richard Kitney OBE FREng	Chairman, UK Focus for Biomedical Engineering
Professor Elizabeth Tanner FREng	Professor of Biomedical Materials, Queen Mary of University London

Speakers

Professor M. John Lever	Professor of Physiological Mechanics and Head of the Department of Bioengineering, Imperial College
Professor David Delpy FRS FREng FMedSci	University College London
Professor Ian Freeston	EC^{uk} and Emeritus Professor of Electronic and Electrical Engineering, University of Sheffield

Discussion Leaders

Dr Octavian Buiu	Dept of Electrical Eng & Electronics, University of Liverpool
Professor Paul Hatton	Centre for Biomaterials and Tissue Engineering, Dept of Engineering Materials, University of Sheffield
Dr Andrew Jackson	Smith + Nephew
Dr Daphne O'Doherty	School of Engineering, Cardiff University
Dr Mark Tooley	Centre for Engineering & Physics Research in Medicine, Bristol University and Royal United Hospital, Bath
Dr Rachel Williams	Department of Clinical Engineering, University of Liverpool

Delegates

Professor Robert Allen	Professor of Biodynamics & Control, University of Southampton
Professor Dan Bader	Medical Engineering Division, Queen Mary University of London
Professor Norman Black	Dean of the Faculty of Engineering, Ulster University at Jordanstown
Dr Joost de Bruijn	Progentix, Bilthoven, The Netherlands
Professor William Bonfield CBE FRS FREng	Professor of Medical Materials, University of Cambridge
Mr Gavin Clarke	BTG plc
Professor Alan Day	Dean of the Faculty of Engineering and Design University of Bath
Dr Professor William Easson	Department of Engineering and Electronics, University of Edinburgh
Dr John Egan	E-tech Ltd,

Professor Norman Fleck FRS	Deputy Head of Department of Engineering, University of Cambridge
Dr Stuart Green	Invibio, Lancashire
Professor Stephen Greenwald	Dept of Histopathology & Morbid Anatomy, St Bartholomew's & The Royal London School of Medicine & Dentistry
Mr David Hall	Chairman of IIE Accreditation Committee
Professor David Hukins	Professor of Biomedical Engineering, University of Birmingham
Professor Z.M. Jin	Medical Engineering, University of Leeds
Professor Garth Johnson FREng	School of Mechanical and Systems Engineering, University of Newcastle
Dr D P Jones	Chair of IPEM Education Panel/Reader in Medical Electronics & Physics, University of London
Mr Brian Kent	UK Focus for Biomedical Engineering
Dr Panicos Kyriacou	City University
Dr Peter Lawes	Apatech Ltd, Queen Mary University London
Professor D A Linkens FREng	Research Professor, Department of Automatic Control & Systems Engineering, University of Sheffield
Dr Sally McArthur	Department of Engineering MaterialsThe University of Sheffield
Dr Brian Meenan	NIBEC, University of Ulster
Dr Richard Neilson	Senior Lecturer, Department of Engineering, University of Aberdeen
Dr Derek Pearson	Chairman of IPEM Accreditation Committee, Nottingham City Hospital Trust
Mr John Robinson FREng	Chairman: George Wimpey plc, Paragon Healthcare Group Ltd, Bespak Plc
Ms Kerry Schutz	Accreditation & Professional Development, Institution of Mechanical Engineers
Dr Ben Stansfield	Department of Bioengineering, Strathclyde University
Professor S Tassou	Head of School of Engineering and Design, Brunel University
Dr Mark Taylor	School of Engineering Science, University of Southampton
Dr Peter Twigg	Lecturer in Medical Engineering, University of Bradford
Professor Tony Unsworth FREng	Head of the School of Engineering and Director of Centre for Biomedical Engineering University of Durham
Mr Mick Wingell	Chairman of the IHEEM Accreditation Committee
Dr Mike Wise	Chairman of IoM^3 Accreditation Committee/ Materials Engineer, Tetronics Ltd
Professor I R Young FRS FREng	Imperial College London

Academy Staff

Mr Keith Davis	Director, Engineering Affairs
Mr Brian Doble	Manager, Engineering Affairs
Mrs Julia Christie	Assistant Manager, Engineering Affairs
Mr David Foxley	Manager, Engineering Design Education

<u>Rapporteur</u>

Dr Anil Bharath,	Imperial College London

<u>Additional written submissions received from</u>

Professor Dan Bader, Queen Mary University of London
Professor Brian Hopkinson, Queen’s Medical Centre Nottingham
Dr Peter Lawes, ApaTech Ltd
Dr Mark Tooley, University of Bristol and the Royal United Hospital, Bath
Dr Amy Zavatsky, University of Oxford