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Abstract: The Medical Engineering team within the School of Engineering, Cardiff University, delivers two postgraduate programmes of study. Established over 10 years ago, the part-time MSc programmes in Orthopaedic Engineering and Clinical Engineering offer the opportunity of further study while remaining within full-time employment. Both programmes deliver 120 taught credits over two academic years via a series of residential weekends, with successful completion enabling the student to undertake and then defend a 60-credit research dissertation. Fulfilling a specific role on the career pathway for both student cohorts, the strength of each programme is indicated by the consistent number of applicants.

Keywords: medical engineering, Cardiff University, postgraduates

1 INTRODUCTION

Cardiff University is a Russell Group university with a thriving research community, including 6000 postgraduate students located throughout 28 academic schools. The University has recently been ranked within the world's top 100 higher-education institutions (HEIs) [**1**], was placed seventh during the latest research assessment exercise, and in 2006–2007 was awarded £110 million from successful research applications.

The School of Engineering at Cardiff University currently has 260 postgraduate students, 140 of which are enrolled on one of the nine taught MSc programmes; two of these lie within the remit of the Medical Engineering team: MSc Clinical Engineering (first intake in 1998) and MSc Orthopaedic Engineering (first intake in 1996).

The MSc Clinical Engineering programme was developed to provide the UK's first educational framework focusing on the development and management of medical devices. It is aimed at employees within the healthcare sector, with or without a degree qualification (but meeting the university general entrance requirement). Currently, the programme typically attracts students from sectors including the National Health Service (NHS), industry, the Armed Forces, or recent graduates who have chosen to follow the career path of a clinical scientist a engineer.

The MSc Orthopaedic Engineering programme provides the student with an understanding and ability to apply engineering to orthopaedic practice. Successful applicants are almost exclusively orthopaedic surgeons; however, applicants have also been accepted from other orthopaedic-related specialisms, e.g. neurosurgery and veterinary surgery.

The aim of both programmes is to provide an education that will supplement the students' current career pathway. It is therefore essential that a student can remain within their current employment while attaining their higher degree, and hence the programme is delivered on a part-time basis, via four residential weekends per academic year. The teaching content is structured to ensure that learning is also achieved within the working environment, as is demonstrable by the work-based projects undertaken following successful completion of the taught component.

The content of both programmes is primarily delivered by in-house staff; however, a close associa-

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tion between the School of Engineering, Cardiff School of Medicine (formerly University of Wales College of Medicine), and Cardiff and Vale NHS Trust ensures the involvement of clinical colleagues.

2 ADMISSIONS

2.1 MSc Clinical Engineering

The MSc Clinical Engineering programme is suitable for graduates currently working within the healthcare sector and hence applicants may include engineers, scientists, doctors, or nurses. In addition, the programme is also open to students without a degree qualification, but who can demonstrate significant experience within the healthcare sector or related discipline; typically this is considered to be 5 years within the industry, 2 years of which should be while typically holding a position of managerial responsibility. The 2007 intake had 14 students, consisting of six candidates from within the NHS, in addition to a trainee clinical scientist (as the MSc programme has the necessary accreditation by the Institute of Physics and Engineering in Medicine (IPEM)); the other applicants worked within the Armed Forces (two) and healthcare industry (five). Seven applicants had previously attained a degree qualification, with the remaining seven holding a Higher National Certificate or Higher National Diploma, in addition to having accrued the necessary experience. Home students accounted for 11 of the 2007 cohort, with another two students residing within the EU and one student being classified as overseas, although resident in the UK (i.e. non-EU). Applications from non-native English speakers require successful completion of either the Test of English as a Foreign Language (TOEFL) (600 points for the paper test, or 250 points for the computer test) or the International English Language Testing System (IELTS) (6.5 points).

2.2 MSc Orthopaedic Engineering

The MSc Orthopaedic Engineering is specifically tailored towards orthopaedic specialists and hence primarily accepts orthopaedic surgeons; however, applicants have previously been accepted from orthopaedic specialists in allied medical disciplines including veterinary surgery and neurosurgery. The programme typically has 40 new students enrolled on year 1, with successful applicants typically possessing a medical degree and membership of the Royal College of Surgeons or Fellowship of the Royal College of Surgeons. Overseas applicants normally practising in the UK comprise approximately 40 per cent of a typical cohort (10 per cent EU, and 30 per cent non-EU) and are required to achieve the above IELTS or TOEFL standard where applicable.

3 PROGRAMME STRUCTURE

Both MSc programmes are offered on a part-time basis, with the primary aim of ensuring that candidates can remain within their current employment while obtaining a higher degree to supplement their career prospects. As defined by the *Credit and qualifications framework for Wales* [**2**], a Masters programme (i.e. level 7) is required to have a 180 credits with a minimum of 150 credits at level M. The programmes at Cardiff University are defined such that the students acquire a total of 120 level-M credits to complete the taught stage of the programme, before undertaking a 60-credit level-M research dissertation. Both programmes include 60 taught credits per academic year, taught over four residential weekends in Cardiff, culminating with a fifth weekend solely for examination. Both MSc programmes benefit from content being delivered by both experienced academic medical engineers and clinical or clinically related colleagues. The MSc Clinical Engineering programme benefits from the input of practising clinical scientists, while experienced orthopaedic surgeons supplement the MSc Orthopaedic Engineering programme. Importantly, this structure ensures that the students are receiving high-quality teaching from experienced academics within a current and relevant industrial or clinical context.

The taught element of both programmes (stage 1) is delivered over 2 years. Years 1 and 2 years are delivered via three to four modules of lectures, example classes, workshops, or laboratory classes (where appropriate). The module assessment typically constitutes 50 per cent coursework and 50 per cent written examination. This format supports the part-time structure, allowing staff to set substantial directed coursework to be completed between residential weekends, while encouraging continued and further 'workplace learning'. This distance learning (which is expected to account for approximately 60 per cent of the student's overall study time) is supported by a number of supplementary resources. The library plus scheme ensures that students can borrow books from their local HEI library, as opposed to borrowing books solely from

the libraries of Cardiff University. The University utilizes the Blackboard online system, which allows for lecture material to be accessed via the internet; in addition, discussion forums are also regularly established to enable students to share ideas, while practice examination questions provide instant feedback. All students are also allocated a personal tutor and have direct access to a dedicated administrator, both of whom are situated within the School of Engineering.

4 ASSESSMENT

Students are required to achieve 50 per cent or more in all assessments to progress to year 2 or stage 2. If any assessment is not passed, the student may, as per the University regulations, carry a year 1 module of not more than 20 credits into year 2; 30-credit modules require a pass during a re-sit examination before the student is permitted to progress. On successful completion of the taught component (i.e. stage 1), students are allowed to apply to receive a postgraduate diploma or to proceed to conduct a research dissertation (i.e. stage 2). The student is assigned a University-based supervisor with whom the focus, organization, and logistics of the project are established and agreed. Additionally, a student can establish a work-placed supervisor to perform research locally, while being supported by the University-based supervisor. Assessment of the dissertation is assisted by a *viva voce* examination, for which the student needs to achieve an overall mark of 50 per cent or more to be awarded a pass; students who have achieved an overall programme average of 70 per cent or more with not less than 65 per cent in their stage 1 assessments and 70 per cent or more at the dissertation stage can be awarded a distinction.

5 PROGRAMME CONTENT

5.1 MSc Clinical Engineering: taught component

5.1.1 Mathematics and Statistics (year 1, 10 credits)

A significant proportion of clinical engineering relies on a firm grounding in mathematics, and hence this module provides the students with an opportunity both to revise and to learn new material. This learning is supplemented by reviewing the appropriateness of techniques published in peer-reviewed journal articles and is intended to be applied during the stage 2 research dissertation.

5.1.2 Clinical Engineering 1 (year 1, 20 credits) and Clinical Engineering 2 (year 2, 20 credits)

In recognition of the diverse backgrounds of the student cohort, both these modules introduce the students to the complex interrelationships between instrumentation, diagnostics, and monitoring within the human body. The year 2 module also introduces the legal concepts, which are relevant to the clinical engineering sector and further introduces the principles of project management and quality systems. The relevance and importance of the content delivered within these modules were emphasized during the most recent (2007) IPEM accreditation visit.

5.1.3 Mechanical Engineering 1 (year 1, 10 credits) and Mechanical Engineering 2 (year 2, 10 credits)

It is also considered essential that the clinical engineering programme delivers fundamental mechanical engineering principles. Initially the students develop an understanding of the principles of mechanics, before developing the necessary skills to apply them to a broad range of engineering applications. These concepts are further developed in year 2, to ensure that students can apply the principles within the clinical engineering environment.

5.1.4 Electronics, Computing and Instrumentation 1 (year 1, 20 credits) and Electronics, Computing and Instrumentation 2 (year 2, 20 credits)

The continuity of the module throughout stage 1 is indicative of the importance of this content to the students. The clinical engineering sector typically involves interaction with digital and analogue electronic equipment and hence a thorough understanding is highly desirable. In the first module, the students learn the key principles of the subject and develop confidence in application to hypothetical clinical scenarios. Further learning in the second module ensures that students achieve a more thorough understanding of the fundamental electronic principles and are able to apply these to unfamiliar clinical engineering problems. Such knowledge is likely to be directly applicable both to the research dissertation and within relevant employment.

5.1.5 Medical Aspects (year 2, 10 credits)

A broad knowledge of human anatomy, physiology, and biochemistry is delivered in year 2, providing

students with the opportunity to appreciate the interrelationship between the clinical engineer, engineering, and the patient. This knowledge is fundamental to any student who wishes to pursue a career in clinical engineering and will inevitably form a foundation of their stage 2 dissertation.

5.2 MSc Orthopaedic Engineering: taught component

5.2.1 Materials and their Properties (year 1, 20 credits)

Providing knowledge of material properties, this module forms a basis from which the student can understand the tissue–implant interface from both a biological and an engineering perspective. This is developed further in year 2 in the Surgical Practice module, allowing the surgeon to appreciate and understand the material-related design considerations of an orthopaedic implant and to be able to identify any potential strengths, weaknesses, and improvements. This area of interest often forms the basis of a student's research and dissertation.

5.2.2 Research Methods (year 1, 10 credits)

By providing students with an overview of research methods and techniques, this module supports the need for surgeons not only to search and appraise the current medical literature but also to access the related engineering literature; the module also serves to support and supplement the student during their research and dissertation stage. Students are assessed on their performance of a literature review and an associated critical analysis. A relevant manuscript and an actual reviewer's comments are then discussed, upon completion of the assignment, to aid student understanding. This knowledge is then of direct benefit for stage 2.

5.2.3 Engineering Theory 1 (year 1, 30 credits) and Engineering Theory 2 (year 2, 30 credits)

Engineering Theory 1 and Engineering Theory 2 introduce the candidates to mechanical engineering, before exploring how these principles can be applied to the human body, and ultimately to clinical practice. To ensure understanding, the year 1 module delivers fundamental concepts of statics, solid mechanics, and the laws of dynamics; these principles are then applied to basic orthopaedic examples. This content is further developed in year 2, to examine the biomechanics of each major synovial joint, e.g. calculating the joint and ground reaction forces. Students also learn to appreciate the common biomechanical causes of joint failure and, following from year 1, to consider biomechanical aspects of implant design. In addition, the students are provided with a thorough grounding in the use and benefits of motion analysis (MA) within a clinical environment and have practical sessions within the MA laboratory. This knowledge is often likely to be drawn upon and developed within the student's research and dissertation, in addition to having direct application within the typical clinical environment.

5.2.4 Surgical Practice (year 2, 30 credits)

The Surgical Practice module is taught exclusively by practising orthopaedic surgeons, with an aim specifically in line with that of the overall programme: to relate the study of engineering to surgical practice. Within the context of this module, this aim is achieved by analysing the common surgical techniques, providing an understanding of the mechanisms of injuries, and gaining an appreciation of the advantages and disadvantages of a variety of implant designs. It is again common for these concepts to be developed further in stage 2, in addition to being drawn upon within the operating theatre.

5.3 Research dissertation

Students on both programmes undertake a 60-credit research dissertation. In many cases the research is based within their place of work or another suitable external organization such as a local university or industrial collaborator. Such a set-up allows a wide range of highly relevant and interesting projects, whereby the students can acquire specialist knowledge and have access to facilities not available within Cardiff University; many of these projects have subsequently been published (see, for example, references [**3**] and [**4**]). A *viva voce* examination allows for the candidate's overall contribution and attainment to be appropriately assessed.

6 CAREER PROSPECTS

Both of the MSc programmes are delivered by the Medical Engineering team at Cardiff University and are structured to supplement the current career pathway of the students.

6.1 MSc Clinical Engineering

The Clinical Engineering programme offers those students without a degree an opportunity to gain the necessary qualifications to seek promotion from their current technical positions. Those students within the Armed Forces are able to study for a further qualification to prepare themselves for life outside the Services, while students following the trainee clinical scientist route need to obtain an IPEM-accredited MSc qualification as part of the continued personal development and advancement towards chartered engineer status.

6.2 MSc Orthopaedic Engineering

The recent restructuring of career pathways within the UK medical profession has significantly increased competition for specialist registrar (SpR) training posts. Subsequently, achieving an M-level qualification in Orthopaedic Engineering is evidence both of further knowledge and a desire to undertake additional learning; these are key criteria of the SpR appointment process.

7 CONCLUSION

The postgraduate programmes offered by the Medical Engineering team within Cardiff University fulfil a specific role on the career pathway for both student cohorts. Consistent applicant numbers indicate the strength of each programme, despite the current financial climate and the continuing evolution of both target audiences.

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