

## **ANALYSIS OF INTERNATIONAL GRADUATE PROGRAMMES STRUCTURES FOR ENGINEERING EDUCATION**

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**Abstract:** This article traces the evolution of graduate study in Engineering in Ireland over three decades. Very few studies have shown the different norms and structures of graduate programmes in Ireland. In this paper, a review of traditional and structured PhD in terms of credit requirements and co-ordination structures is presented. The authors summarise the characteristics of graduate programmes in different universities in Ireland and compare these to those obtained in some of the leading international universities. The implementation of graduate programmes in Ireland is relatively recent and the structure of these programmes is still under development in the different universities. Plans for enhancement of graduate programs and the development of new initiatives to support graduate student academic and professional development are very important for the success of these programmes. The growth in enrolment reflects a broad diversity in background of students which will require not only increased financial resources but an adequate and sound organisational structure in order to move forward.

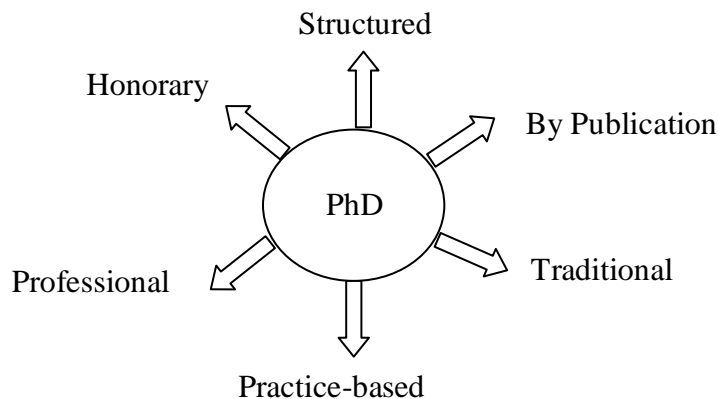
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### **1. INTRODUCTION**

The Doctorate Degree covers many fields of specialisation and requires a minimum of three to four years of study beyond the Bachelor's degree. Doctorates in Education, Science and Law are sometimes labeled Ed.D., Sc.D., Jur.D., but most doctorates are known as Ph.D. (Doctor of Philosophy) degrees. To obtain a Ph.D. degree, the university generally requires that a student fulfil some combination of the following (Fulbright, 2010; QAA.2001): Earn a certain number of credits in a required distribution of courses; Maintain an average grade second class honours degree; Pass a qualifying comprehensive examination after completion of the required courses; Pass examinations in one or more foreign languages; Present and defend a thesis which is the result of original research; and Pass an oral examination.

The European University Association completed a major research project on 'Doctoral programmes for the European knowledge society' in 2004/2005 (EUA a, 2005). This examined key issues concerning the structure and organisation, financing, quality and innovative practice in doctoral programmes across Europe. It involved six networks comprising forty-eight universities from twenty-two countries. There are six different types of recognised PhD degrees which are shown in Figure 1.



**Figure 1: Typical PhD degrees** (after NQAI, 2006; Scott d. et al. 2004)

Honorary doctorates are given for the exceptional contribution to society. With the exception of the honorary doctorate the major component of all doctorates is original research. Doctoral degree by publication is based on published work rather than a thesis. A thesis in combination with a creative work in the visual or performing arts is known as practice based Doctorate. Without a thesis, based on professional extra ordinary achievement, Professional Doctorates are awarded. In the traditional model, a PhD is awarded after defense of a submitted thesis without classification. Taught modules are generally not part of a traditional PhD model. Subject to its successful completion, the thesis can have a nominal value of 270 ECTS credits and requires at least 240 credits worth of advanced research at level 10 (Scott d. et al. 2004). There are a number of differences with respect to credit. Firstly, not all programmes are modularised and therefore are not credit-based. Secondly, where credit-ratings are specified, they differ between institutions and do not generally indicate whether all the credit is at doctoral level. Candidates who wish to pursue a structured PhD program would generally take not less than 300 credits. A research thesis equivalent to 270 ECTS credits and 30 ECTS credits for taking offered modules.

Regulations, Policies and Codes of Practice are different in different universities. Most programme structures are built in conjunction to the academic regulations for postgraduate degrees by research and thesis. These regulations are designed to safeguard both the academic standards of the University and the interests of individual students graduating from the university.

### *1.1 Advantages of structural PhD*

Two criticisms of the traditional PhD in terms of its narrow focus are the limited set of skills acquired by PhD candidates and its isolation in general from the work place, see Scott, Brown, Lunt and Thorne (Scott et al. 2004). They and others (Green, Maxwell and Shanahan, 2001) (Scott D. et al. 2004; Maxwell et al., 2000, 2003) note the parallel growth in the Structural Doctorate and key shifts in the relationships between universities and the State and new understandings about knowledge (production/creation and form). Structured PhD programmes reflect on the range and nature of appropriate transferable skills and to reconceptualise students as people gaining work experience, and as early stage researchers. As a result students are involved in terms of professional work experience and are more oriented towards the workplace. Strong links with employers of graduates, who have a strong orientation towards the fields of

education, can be achieved ensuring that research focus is now an active consideration. These partnerships include potential for mobility placements for staff and students, summer schools, joint course delivery, joint supervision, organisation of workshops and conferences

## **2. STRUCTURE GRADUATE PROGRAMMES IN IRELAND**

### *2.1 Higher Education Authority*

There are seven universities in the Republic of Ireland. The University of Dublin, Trinity College, founded in 1592, is the oldest university in the country. The National University of Ireland (NUI) consists of four entities: National University of Ireland, Galway: National University of Ireland, Maynooth: University College Cork: and University College Dublin. The two newest universities, founded in 1989, are the University of Limerick and Dublin City University. There are fourteen Institutes of Technology, located throughout Ireland. These are government-funded institutions, offering courses at undergraduate certificate, diploma and degree levels. They also offer graduate programs, mainly by research. The Higher Education and Training Awards Council, under the National Qualifications Authority validate their qualifications. In addition to the publicly funded institutions, there are a number of independent third-level colleges, several of which offer graduate programs.

While Ireland has long enjoyed a high reputation as a culture centre, the government has also regarded investment in technology based higher education disciplines as key element in our national economic development. As a result of this investment, Ireland has developed a highly qualified workforce and has attracted considerable inward investment. Over the past 20 years, Ireland has grown into being a leading exporter of computer software, computer hardware, pharmaceuticals, and biomedical products. At the undergraduate level Bachelor's degrees consist of four years of study with this currently changing to a five year structure (as per Bologna guideline). This is followed by a range of graduate options, entry to most of which require a high level of honours Bachelors degree award.

PhDs in Ireland are generally by research and normally would be expected to take a minimum of three years. Students work under an academic supervisor and carry out research leading to the publication of a thesis that shows evidence of original work which presents a significant contribution to the related research area. Availability of places depends on the availability of an academic supervisor in the candidate's area of specialisation and funding availability (SFI, 2010). There is increased attention given by third level institutions, government agencies and research councils to research and train at doctoral level and the development of graduate schools in the context of developing a knowledge society. The Irish Universities framework proposal for the '*Reform of 3rd Level and Creation of 4th Level Ireland*' (2005) emphasises the need for new types of graduates at the 4th level (IUA, 2010). It illustrates this with reference to the need for a new model of structured PhD programmes with taught courses, training and formalised career development. These would be characterised by flexibility, responsiveness and inter-institutional and stakeholder collaboration. These proposals do not specifically address implementation methods for the Structural Doctorate but address the need for 'radical modernisation of PhD and post-doctoral training' to meet the needs of the knowledge society. These guides and the growth of Graduate Schools point to the ever increasing development and availability of structured PhD programmes in the future. In 2002/2004, The Irish Universities Quality Board carried out a research project on Good Practice in the Organisation of PhD programmes in Irish universities. The aim of the project was to improve the organisation and efficiency of PhD programmes in all Irish universities. At the outset of the project, it was decided to exclude non-PhDs and higher

doctorates from the project (IUQB, 2004). The project led to the development of '*Guidelines for Good Practice in the organisation of PhD programmes in Irish universities*' in 2004. These address themes including administration, supervision, research project, induction and professional development, dissertation and examination. The Higher Education and Training Awards Council (HETAC), in 2003, issued similar guidelines for post-graduate research, which included doctorates (HETAC, 2003).

## *2.2 Overview of national practice*

Information provided by the universities to the Higher Education Authority does not distinguish between different types or titles of doctoral programmes (HESA, 2007). It should be noted that a number of institutions offer structured PhD programmes with substantial taught elements (e.g. PhD programme in Biomedical Sciences, Royal College of Surgeons of Ireland (RCSI) and in some cases, leading to named doctorates.

### *Entry requirements*

There is some consistency in entry requirements for Doctorate programmes. These usually include specific performance in a Masters Degree and professional practice 'at an appropriate level' as determined by the institution offering the programme. For entry to some programmes, professional practice may not be required but can be taken into account. The academic qualifications required vary from 2<sup>nd</sup> class honours to masters. In exceptional cases, candidates who have not met all the relevant criteria may be accepted onto some programmes.

### *Specification of learning outcomes*

The extent to which learning outcomes are specified or made explicit in programme material is mixed. It is possible that these are made more explicit in internal course approval/validation documentation or are inferred from programme aims and objectives. In some cases, they are clearly stated and published but in the majority of cases, this is not so. In some cases, learning outcomes are specified for modules only. The degree to which learning outcomes are specified appears to relate to the field of study/profession and general institutional practice. It would appear from the material available that the learning outcomes are at the same level as those specified in the descriptor for the Doctorate at level 10 in the national framework of qualifications.

In Trinity College Dublin, students participating in the structured PhD programme or seeking to transfer to the PhD register must participate in a set of modules agreed between the student, research supervision team, and the Postgraduate Director. Thirty units within the European Credit Transfer System (ECTS) must be earned prior to confirmation on or transfer to the PhD register. The normal distribution of credits is as follows: 5 ECTS in Research Methods; 5 ECTS in Introduction to Statistics and 20 ECTS which can be in the form of directed studies modules, from the pool of modules available in the School, or from other externally certified taught modules (such as from partner universities or summer schools). In University College Dublin, a Doctoral Studies Panel is appointed normally in early first year. The purpose of this Panel is to support and enhance the supervisor-student relationship, to monitor progress during the course of doctoral studies and to provide advice and support both student and supervisors. Research and professional development planning is an integral part of this Structured PhD programme. The purpose of such planning is to ensure that student's work is clearly focused on achieving research and professional development goals. This will play a major part in informing the trajectory of PhD research, training and development. This Structured PhD operates within a credit-based framework, with one credit corresponding to 20 to 25 hours of total student effort. If undertaking a 3-year PhD programme, student can earn 30 credits by attending modules that

develop academic and transferable skills. There are structured PhDs in Bioinformatics and Systems Biology and Software Engineering at University College Dublin. In the University of Maynooth, for humanities e.g. Economics, geography and business there are compulsory structured PhD but, there are no compulsory structured PhD programmes for technology related awards. There are however optional graduate modules available. In Dublin City University (DCU) there are structural PhDs for humanities and business. In engineering, DCU partakes in two national level graduate school programmes, one in photonics (INSPIRE) and another in software engineering (LERO) funded through government PRTLTI programme. St. Patrick's College Drumcondra (SPCD) has two Faculties' humanities and Education. Since 1993 it has been a College of Dublin City University and all courses are accredited by the university. Discussion is underway at present with DCU as part of SPCD's planning and foresight process with the possibility of more formal links in the delivery of graduate programmes. To this end, the SPCD-DCU linkage management committee has as one of its functions facilitation of joint programmes and central among these are structured graduate programmes, in particular in education and within the Education-Humanities spectrum.

### **3 INTERNATIONAL GRADUATE PROGRAMMES**

#### *3.1 America*

The Research Doctorate represents the third and highest stage of higher education in the United States and may be awarded in academic disciplines and some professional fields of study. This degree is not awarded by examination or coursework only, but requires demonstrated mastery of the chosen subject and the ability to conduct independent, original research. Doctoral programmes require intensive study and research in at least one subfield and professional level competence in several others. Following a series of research seminars designed to prepare the individual research proposal, candidate examinations (covering at least two subfields in addition to the field of research focus, one of which must be in a subject outside the doctoral student's own faculty but related to his/her research). If the candidate examinations are passed at a satisfactory standard (excellent or higher), the student is advanced to candidacy for the doctorate and selects a research committee of senior faculty who will approve the dissertation topic, monitor progress, and examine the student when the research is finished. The conduct of research and preparation of the dissertation can take anywhere from one to several years depending on the chosen subject, available research funding, and the location of the research. When the dissertation is finished and approved as a document by the chair of the research committee, that individual convenes the full committee plus any outside faculty and public guests and presides over the candidate's oral defence of the dissertation. A unanimous vote of the research committee and examiners is generally required to award the doctorate. Most doctoral degrees take at least 4 or 5 years of full-time study and research after the award of a Bachelor's degree or at least 2 to 3 years following a Master's degree. The actual time to obtain the degree varies depending upon the subject and the structure of the programme.

The University of Massachusetts Medical School (UMMS) is nationally ranked for its excellence in research, health care and health sciences education, while Worcester Polytechnic Institute (WPI) is ranked as one of the best engineering schools in the Northeast. Capitalising on these factors, the Graduate School of Biomedical Sciences (GSBS), UMMS and WPI initiated a joint PhD program in Biomedical Engineering & Medical Physics in 1996. This formal program employs the advanced technical expertise of engineering and medical faculty and utilizes the experience and resources available from a public research university and a private institute of

higher education to train students in the application of engineering to medical research. Graduates of the joint PhD program are prepared to work as faculty of academic institutions or as employees of the growing medical device and biotechnology industries that have seen major economic growth in Massachusetts. Due to the highly specialized nature of the program, it is open only to those applicants who already have an undergraduate degree or a strong background in mathematics, physics or engineering. Applicants are also expected to have had one semester of organic chemistry and a full year of biology. Course of Study Prior to completing qualifying examinations, students spend approximately two years taking advanced biomedical science and engineering courses at UMMS and WPI. Flexibility is allowed for specific course requirements based upon students' backgrounds and areas of interest. Since the two campuses are only ten minutes apart, laboratory rotations, courses and seminars can be taken simultaneously during the first two years. The joint program also offers shared courses and options to do thesis work at either institution. Committee structure, qualifying examinations and dissertation defences follow the same basic format currently used by the GSBS, with the exception that all committees are made up of representatives from both institutions. The program is for full-time students, for a minimum of at least three years (residency requirement). Approximately 90 credits of graduate-level courses and thesis research are required, and the PhD in Biomedical Engineering is awarded jointly by WPI and UMMS, with the appropriate designation on the diploma.

### *3.2 Europe*

There is a range of models of graduate schools in the UK and other European countries. EU funding for inter-institutional doctoral programmes has recently been made available, Erasmus Mundus (EACEA, 2009). Since the 1990s most UK universities have structured their doctoral provision around graduate schools, although the nature and remit of these vary widely (UKCGE, 2004). In the UK, graduate schools tend to be a governance structure that spans the institution or individual faculties and schools. They facilitate the strategic management and coordination of postgraduate provision and provide a means of representing postgraduate interests at an institutional level. In many cases, graduate schools cover both doctoral researchers and taught postgraduate students. Other models within Europe include 'doctoral' or 'research' schools focusing on specific research themes, often across a number of institutions, where membership and access to facilities or resources might be restricted to select groups of doctoral candidates, such as the German 'excellence initiative' (DFG,2009). At a European level, the European University Association's Council for Doctoral Education, launched in 2008, was set up to support discussion among European universities about the development of doctoral programmes (EUA b, 2009).

### *Bologna Third Cycle*

The issue of doctoral studies is under continual discussion in the Bologna process. The Bergen communiqué, June 2005, called for the 'further development of the basic principles for doctoral programmes, to be presented to Ministers in 2007 (Bologna process a, 2005). The Bologna seminar on 'Doctoral programmes for the European knowledge society already took steps in this direction in that it reached agreement on ten basic principles that should underpin further considerations of the key role of doctoral programmes and research training in the Bologna process (Bologna process b, 2005). The Bergen communiqué also states that doctoral level qualifications need to be fully aligned with the EHEA overarching framework for qualifications using the outcomes-based approach'. A declaration on professional higher education was made by rectors conferences and associations representing higher education institutions outside the university sector to the Bergen Ministerial meeting (2005). This emphasised the importance of

this strand of higher education and of the professional doctorates. The implementation of the Bologna protocol in the European Union has set new goals for the whole higher education system as: (a) a quality assessment for university courses; (b) a framework for the exchange of students and academics; and (c) an opportunity for changing the teaching/learning procedures and methodologies (Teixeira et al., 2007). The doctoral cycle of the Bologna process (Bologna Process third cycle, 2008) endorses the development of appropriate organisational structures in the form of doctoral, research or graduate schools. Organisational structures chosen must demonstrate added value for the institution, in particular in seeking to: counteract the isolation of the young researcher from other disciplines, or from the larger peer group, or the larger scientific community; establish transparency of expectations, quality and assessment standards (supervision etc); and create synergies regarding generic skills training (at institutional or at interinstitutional level). The structured PhD programmes which are increasingly a feature of doctoral education in the UK, Ireland and Europe generally respond to criticisms of the traditional PhD programmes and meet new demands. It is envisaged that the European Community will as a matter of policy continue to provide finance for co-operative research and for staff and student mobility across national boundaries (McCABE, 1998). Many departments of engineering will experience significant changes in attitudes to the industrial world and to course structure to meet student mobility if departments are to fully meet the challenges and opportunities posed. The provision of adequate financing will be a permanent problem and more use will be made of industrial sponsorship, research contracts and EC research contracts. Programmes of instruction, even in the same country, will no longer be of the same invariable monolithic structure and the division between professional and sub-professional engineering courses will no longer be as sharp or clearly defined as in the past. Co-operation and interaction with institutions in other countries in research and teaching together with staff and student mobility will contribute significantly to the interest, efficiency and value of the schools of engineering at the turn of the century.

#### **4 CONCLUSIONS**

Advanced training is becoming an increasingly important element in graduate research. The intention of such training is to produce researchers with a broader approach to problem solving and more attuned to later career opportunities within the relevant industrial and business sectors. Graduate training involves additional educational and training elements which develop advanced knowledge, skills and competencies required for successful original research. Such training supports the acquisition of both significant disciplinary learning and more generic transferable skills, while also making students aware of possible opportunities to commercialise and further their research. Generic skills of advantage to the graduate trainee include technical writing, presentation, tutoring and demonstrating, research design, qualitative and quantitative research methods, operations research, programming, commercialisation, and research ethics courses. The structure of Professional Doctorates varies significantly depending on the discipline and/or professional field relevant to the programme. In general terms, programmes include substantial taught elements (in some cases with some overlap with Masters programmes) which can be transdisciplinary as well as disciplinary, project work and a thesis. They can be designed to allow for flexible, part-time delivery and a mix of taught, research and thesis components. Block mode delivery of modules in shorter time periods has proven most flexible for various institutions, postgraduate students and outside interested participants. There is variation in the number of taught modules and project work involved and in their share of the overall doctoral programme.

Although the measured in terms of credits and duration varies from case to case, coursework and thesis form a part of every programme. The need to raise Science and Technology (S&T) knowledge and skills in order to serve national educational, economic and entrepreneurial goals requires the implementation of a coherent structured PhD. By stimulating interest in S&T and by increasing student participation in traditionally problematic subject areas, future employability and S&T literacy can be enhanced. A multidisciplinary approach will enable graduates to address problem solving within real-life situations and more readily identify more optimised problem solutions. Structured PhD programmes are increasingly common across Europe as are collaboration between institutes of higher education and research institutes in doctoral training.

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