The Industrial Doctorate – Career Strategies and Employer Engagement in Research Training [1]

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Abstract

This paper examines forms of industrial involvement in doctoral education for the new competence building, workforce skills development and the formation of "hybrid spaces" between academic and industry through mobility of talents. Knowledge exchange activities between university and industry have direct and indirect education implications for doctoral students and their research experiences. Nevertheless, empirical research with regard to the educational impact of university-industry relationships and implications for research training is in short supply. The paper looks at the development of 'industrial doctorate programmes' in the UK over the past decade in relation to the wider international debates surrounding the changing nature of doctorate degrees and forms of employer engagement. Empirically, the aim of this study is to understand the 'learning experiences' and 'strategies' of industrial doctorate students at EPSRC funded Industrial Doctorate Centres (IDCs) while they conduct doctorate research within the industrial contexts. The pilot survey with the 25 industrial doctorate students enrolled at EngD in Systems illustrates institutional complexity of working between "hybrid spaces", managing different expectations and solving industrial problems with academic inputs and support, as well as acting as 'change agents' within organisations.

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1. Introduction

It is argued that the competition for ideas, knowledge and skills defines the new economy (Drucker, 1993), where new models of organisations and employment are required to cope with rapid technological innovation and change (Lam, 2007). The increase in educated labour is considered to be ‘a power shift’ where human and intellectual capital - individual expertise, knowledge and creativity – generates prosperity for individuals, companies and nations (Brown et al. 2008). Consequently, along with an increased expectation of the role of universities for innovation and economic development from research and commercialisation of knowledge they generate, there is growing interest in the production of new forms of ‘high skilled’ workforce. Since the 1990s, countries around the world have been increasing ‘doctoral degree production’ (Nerad, 2010), and there is a growing interest in new forms of doctoral education and research training in different national contexts (Harman, 2004; Enders, 2005; Nerad, 2010; Servage, 2009; Thrift, 2009).

Issues concerning doctorate education and research training are discussed from two different angles. On the one hand, the needs of the knowledge economy have increased the demand for doctoral-level research abilities in governments, research institutes and private industry alike, while on the other hand, doctoral education has been seen to have failed to meet the needs of industry and society, and has thus created “misalignments and inefficiencies in the employment market for graduates” (Servage, 2009, 765). Reforms in doctoral education, particularly the perceived need to make stronger links with industry and employers are an international and transnational phenomenon and pertinent given the growth in doctoral students, their eventual destinations (e.g. Stephan et al., 2004; Lee et al., 2010). These are associated with a number of common issues surrounding doctoral training and education such as low completion rates, and mismatch between academic research and industry needs. Responses to these issues are found in the emergence of new types of coordination between science and technology, and new types of PhD labour market (Mangematin, 2000). Lanciano-Morandat and Nohara (2006) and Lam (2007) developed the concept of “an intermediate labour market” and “overlapping internal labour market” between academia and industry, interacting between the two spaces.

This paper examines forms of industrial involvement in doctoral education for the new competence building, workforce skills development and the formation of “hybrid spaces” between academic and industry (Lanciano-Morandat and Nohara, 2006; Lam, 2007; 2010) through mobility of talents. The broad underlying questions underlying this paper are as follows:

- How can universities better work with employers to meet the needs of high-level, especially, doctorate level, skills and competence building? ;
- What forms of skills and workforce development are possible through mobility of talents between university and industry and how can they be reflected in human resource management?
- What funding and institutional mechanisms are needed to achieve circulation of knowledge and formation of competence and skills through the mobility of talents between university and industry?
- How do doctoral students learn through such mobility experiences and how would that be embedded within an industrial context?

The focus of this paper is industrial involvement in doctoral education as one type of "university-industry relationships" (Perkmann and Walsh, 2007) at different stages of career development of employees. It takes different 'human mobility' forms including short term secondments, financial arrangements to fund doctoral students, and co-supervision of doctoral research projects between academia and industry. These forms of relationships are not so new; many have developed over the last decades. The mobility of scientists and researchers including doctoral students are conditioned by wider employment relationship and labour market and training mechanisms of each national system. The empirical focus of this paper is on a particular type of provisions for employer engagement with higher education, related to specific 'high-skill' research training provided at doctorate level. The paper looks at the development of 'industrial doctorate programmes' in the UK over the past decade in relation to the wider international debates surrounding the changing nature of doctorate degrees and forms of employer engagement with roles played by research councils, industry associations, employers and universities.

The structure of the paper is as follows. Following this Introduction, the Second Section provides review of background literature in two related fields: a) knowledge production and knowledge flows between academia and industry, especially through human mobility, and b) Science and Technology (S&T) human capital, labour market and careers of researchers. Based on the review of literature, the paper introduces the conceptual framework of the paper is presented, drawing on recent literature on "hybrid spaces" (Lam, 2007; 2010) between academia and industry, learning and competence building (Lanciano-Morandat and Nohara, 2006). There are different career structures and incentives for academics and those who work in industry, and "entrepreneurial academics" or "linked scientists" are one type of people who move between the two spaces (Lam, 2007). Those doctoral students who pursue industry career can be seen as another type of mobility between "hybrid spaces". In the Third

Section, the empirical context of this paper is presented, by providing a chronological review of a development of Engineering Doctorate/Industrial Doctorate Centres (IDCs) in the UK, with recent policy debates. The Fourth Section presents empirical observations based on the recent study enquiring strategies and learning processes of industrial doctorate students who move between the university and industry. The paper concludes by identifying different motivation, strategies and learning processes of employer engagement in doctorate education, in relation to the current policy agendas in the UK. Finally, further research agendas are identified.

2. Human mobility as University-industry relationships and development of S&T human capital

Bozeman et al. (2001) define Science and Technology (S&T) human capital as *the sum of scientists' and engineers' scientific and technical knowledge, work relevant skills and social ties and resources* (Bozeman et al., 2001). This paper focuses on S&T human capital building mechanisms, and takes a view that industrial engagement in doctoral education is one type of university-industry relationships, which enhances S&T human capital, with increased interactions with external agents. Such relationship develops over years in different national policy contexts, within national innovation systems (see Mowery and Sampat, 2005; Howell et al 2008). This paper draws on, and aims to synthesise the academic literature focusing on a) knowledge production and knowledge flows between academia and industry on one hand, and b) S&T human capital, labour market and careers of researchers on the other. In other words, in order to understand the processes of learning and competence building, and knowledge production and innovation, with employer engagement at the Industrial Doctorate Centres (IDCs), two inter-related issues embedded within the industry-university collaboration need to be unpacked - one is concerned with "the joint production of new knowledge with commercial applications", and the other related to the "patterns of careers and incentives". These are underlined by "the divergent work norms and reward structures governing the two different knowledge production systems" (Lam, 2007, p. 997).

Referring to the intersection between the two different knowledge production systems of industry and academia, significant "barriers" (Bruneel et al., 2010) are identified. These are related to the nature and orientation of different types of knowledge (Harryson et al., 2008; Chiang, 2011). According to Harryson et al., (2008) this is characterised as "a fundamental difference between corporate and academic research: scientific knowledge produced by companies is usually claimed to be short- and medium-term oriented, aiming at exploitation, whereas the strength of academic research is claimed to prevail in exploration, but seldom comes up with results ready for commercialisation"(Harryson et al., 2008, p.113). Rather than looking at these corporate and academic spheres of knowledge production systems in a dichotomy, a more interlinked perspective seems helpful. Two "modes of learning and innovation" have been identified by scholars in innovation research. One mode is based on "the production and use of codified scientific and technical knowledge", the *Science, Technology and Innovation (STI)* mode, and the other one is "an experienced-based mode of learning" based on *Doing, Using and Interacting (DUI-mode)* (Jensen et al., 2007). It is argued that firms that use mixed strategies that combine organizational forms promoting learning with R&D efforts and with co-operation with researchers as knowledge institutions are much more innovative than the rest. In other words, it is argued that the firm that "combines a strong version of the STI-mode with a strong version of the DUI mode" excels in production innovation (Jensen et al. 2007, p.685). In this light, knowledge production systems within corporate and academic research spheres interact each other and they are interdependent.

Today universities are encouraged by various policy and funding instruments to actively engage in the diffusion of research based knowledge by multiple routes, including commercial channels − licensing patents, consulting, or implementing knowledge through spin-off companies; as well as more relationship-based knowledge transfer activities (Perkmann and Walsh, 2007) − collaborative research, commissioned research, consultancy, equipment sharing, advisory roles, joint supervision, joint publication and student placements. Thus, recent studies demonstrate a variety of university-industry 'links' and 'relationships' evolving between them and inter-linkages between different channels. Patel and D'Este, for example, based on the survey with the UK engineering and physical scientists, concluded that researchers use a wide variety of such channels, such as consultancy and contract research, joint research, training, meetings and conferences, and the 'creation of new physical facilities' (e.g. 'spin-off' companies).They find that a significant number of academics are engaged in several channels simultaneously, particularly in the applied sciences. A comprehensive review is provided by Perkmann and Walsh (2007) on the academic-industry "relationship-based" mechanisms such as research partnerships and research services, in relation to other mechanisms related to 'transfer' and 'mobility'. These *typologies* of university-industry links coexist with different types of knowledge flows, such as scientific codified knowledge and informal social interactions.

Table 1 Typology of University-Industry linkages
Based on: Perkmann and Walsh (2007)

Relationship based	**Research partnerships**	Inter-organizational arrangements for pursuing collaborative R&D
	Research services	Activities commissioned by industrial clients including contract research and consulting
Mobility based	**Academic entrepreneurship**	Development and commercial exploitation of technologies pursued by academic inventors through a company they (partly) own
	Human resource transfer	Multi-context learning mechanisms such as training of industry employees, postgraduate training in industry, graduate trainees and secondments to industry, adjunct faculty
Transfer Based	**Commercialization of property rights**	Transfer of university-generated IP (such as patents) to firms, e.g. via licensing

The focus of this paper, the industry engagement with doctorate research training falls between relationship-based and mobility-based university-industry links. By contrast, human mobility aimed at transferring 'generic skills', such as graduates seeking work in industry, is part of a more infrastructural role of universities and is therefore not classified under the relationship category according to Perkmann and Walsh (2007). As Perkmann and Walsh argue (2007, p.263):

> Relationships will often occur in conjunction with human mobility: for example, when companies sponsor Ph.D. studentships. In fact, in many cases, mobility can be intrinsic to relationships if it occurs within the context of specific collaborative projects.

In the context of 'open innovation', the links with high "relational involvement" are considered to be relevant to innovation, as they facilitate the building and maintenance of inter-organizational relationships over a prolonged period of time. There are differences in the preference of different 'relationship' mechanisms in different industrial sectors with various levels of interaction intensity and intensity of R&D. According to a study by Schartinger et al (2002) in Austria, collaborative research is preferred to contract research in the chemicals, instruments, metals and automotive sectors, while the opposite is true for software development. Relationship in the form of training and education, by contrast, are used mainly by the service industry. It is interesting to investigate further how mobility creates different sets of 'relationship' mechanisms in different industrial sectors.

Little is known about "how the flow of knowledge across organizational boundaries is intertwined with careers and employment relationships" (Lam, 2007, p. 994) in relation to the systems of training and competence building at firm and national levels. Furthermore, since tacit knowledge is embodied in personnel, it is interesting to look at "the role of the functions and the qualifications of R&D personnel in relation to activities developed in the framework of technical collaboration agreements" (Spithoven and Teirlinck, 2010).

Recent literature on skills and workforce development argues for 'pro-innovation' organisational practices (OECD, 2010, p. 11) for innovation at work places:

> Learning and interaction within organizations is at least as important for innovation as learning through interactions with external agents, and indicators for innovation need to capture how material and human resources are used and whether or not the work environment promotes the further development of the knowledge and skills of employees.

In terms of training, workforce development and employment relationship at a firm level, there is an association between the "propensity of firms to innovate and the probability of them providing workplace training" (Toner, 2011, p.32). There is increased interest in the literature on skills and innovation on the "links between the propensity and intensity of innovation in firms and the different forms of innovation activity that firms and industries can implement and the adoption of specific work organisation patterns" (OECD 2010 cited in Toner, 2011, p.53). It is argued that the supply of vocational education and training (VET) skills is influential in determining not only what goods and services are produced in a national economy, but how they are produced. Firms' product market choices are constrained by the availability of necessary skills (Toner, 2011, p.35).

The literature on the "institutional foundations of national skill formation regimes" identifies three broad types of intermediate skills formation systems; 'occupational', 'internal' and 'flexible' (Hall and Soskice, 2001). These types of labour market models are a set of "self-reinforcing institutions", which create "economic incentives and legal and social obligations" on workers and firms to "invest in particular forms of workforce training and for firms to adjust their production systems and products to these particular types and level of skill" (Toner, 2011, p.35). These labour market models may define the types of innovation and skills required in each system. For instance, German VET system is supported by national institutional mechanisms, which suits the "occupational labour market model." In such a model, vocational skills are characterised by "deep competencies within established technologies" (Estevez-Abe *et al.*, 2001, 174), which are particularly "suited to incremental innovation and problem-solving but are inappropriate to a world where competition is dependent on rapid changes in basic innovation" (Lauder, 2001, 170). In the UK and US, the education and training systems have been effective at innovation based on "high level elite skills in science and technology" (Toner, 2011, p.50) derived from world class universities. These are particularly eminent in industries such as pharmaceuticals, chemicals, electronics, software, defence and aerospace indicated by, measures such as R&D intensity, trade performance and patenting activity shows the strength of this high level science base (Toner, 2011, p.50). High level skills also underpin international competitiveness in financial services and creative industries like advertising, publishing, design, entertainment and management consulting (Tether *et al.*, 2005: 70). The absence of labour market regulations on hiring and firing and high levels of job mobility, including amongst the "scientific, engineering and managerial elites", is well suited to industries such as software, finance and biotechnology (Toner, 2011, p.50). These sectors are reliant on "rapid product innovation strategies" and a "high responsiveness to new business opportunities" (Estevez-Abe *et al.*, 2001: 174). A high level of labour mobility, especially amongst the "technical elites", is also a critical means of technology diffusion in industries in which change in technology and markets is particularly rapid (Finegold, 1999, cited in Toner, 2011, p.50). This leads to the two questions. One is concerned with researchers' career, incentives and disincentives for mobility, and reward mechanisms as part of the firms innovation strategies; and the other concerns development of the skill set of researchers and the systems through which researchers are trained.

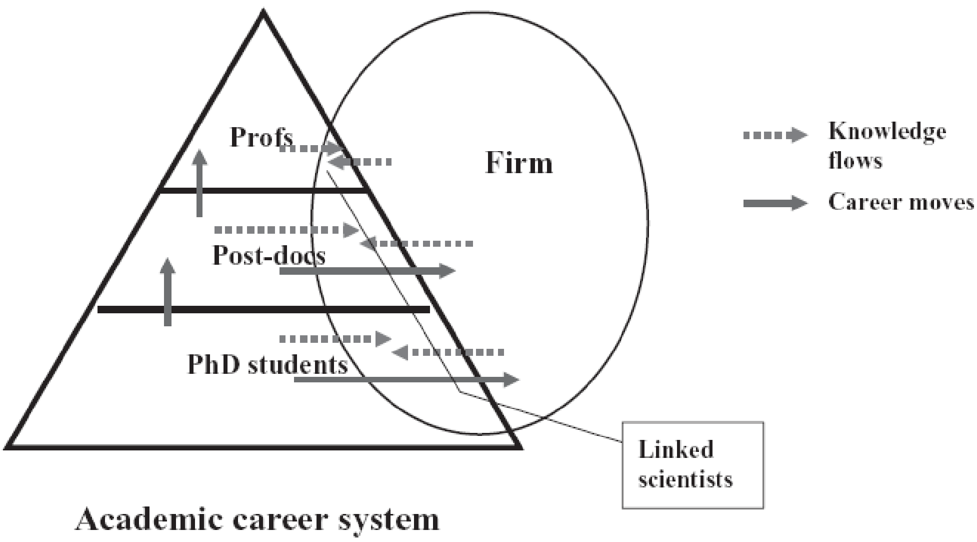
The new scientific labour market is characterised by the formation of competences on a collaborative basis between academia and industry, through the creation of joint "pool of human resources" (Lam, 2007, p. 1005). Authors have called such human capital as "the linked scientists" (Zucker et al., p. 2002), whose work roles and careers straddle the world of the university and the firm. According to Lam (2007), three types of 'linked scientists' are identified:

- Entrepreneurial professors
- Post-doctoral researchers
- Doctoral students.

Lam (2007) focuses on the ways in which firms build close links with the university partner and develop “network career structures” engaging academic scientists in the process of joint knowledge production. On the other hand, a growing body of work, both in the academic literature and other public documents, examines researchers’ motivation and attitudes toward knowledge diffusion within and outside academic contexts. Jacobson et al. (2004), for example, identifies “the reward and incentive system” in academia as the main barrier for knowledge transfer (p. 248). Figure 2 below presents academic career system in a schematic way, with “linked scientists” who connect academic career system and an organisational knowledge production of a firm through network forms of organisations. This model represents career of *academic scientists* who engage in ‘entrepreneurial science’ collaborating with industry (see Lam, 2007, p.1005-1010).

Figure 2 Academic career system and ‘linked scientists’

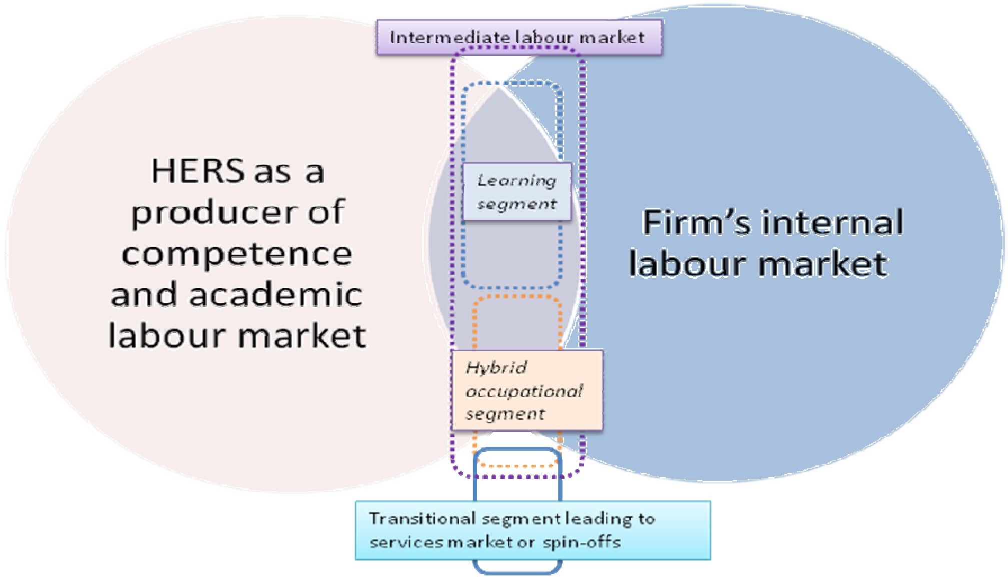
Source: Lam 2010



Doctoral students are seen as ‘linked scientists’ whose competences are jointly produced jointly by actors and stakeholders in both academic institutions and industrial organisations (e.g. academic supervisors, industrial supervisors, academic and industrial peers). According to Lanciano-Morandat and Nohara (2006), human actors, such as researchers, post-docs, professors and doctoral students play a central role in the “structuring of the *hybrid space* that is emerging at the interface between academia and industry” (Lanciano-Morandat and Nohara, 2006, p. 280). In Figure 3, the interlink between the two labour market systems ‘an intermediate labour market’ between academia and industry is schematically presented.

Figure 3 Intermediate labour market between academia and industry

Source: Lanciano-Morandat and Nohara, 2006



Arguably, the formation of competences is increasingly taking place on a collaborative basis between the two spheres, in a so-called "overlapping intermediate labour market" (Lam, 2007, p.1013). Growing share of scientists is being 'jointly produced' by the higher education and research system (HERS) and firms, which Lanciano-Morandat and Nohara (2006) call 'learning segment'. The relationships between the two spheres give rise to networks and circulation of researchers, which they call 'hybrid occupational' segment (p.282), or what is called "network forms of organisations". The empirical part of this paper illuminates the ways in which individuals strategically construct their knowledge spaces within the 'internal labour market' with 'learning' and 'hybrid occupational' segments and what challenges and constraints they face through the processes.

3. Contextualising Reforms in Doctoral Education, Engineering Doctorate and Industrial Doctorate Centres

Mangematin (2001) points out the special nature of "doctoral manpower" – they are trained to produce new knowledge and serve as an important channel for knowledge transfer from academia to industry if they enter industry after their doctoral education. The graduate student is characterized as, in short, 'the workhorse of the modern laboratory' (The Economist 2007). In particular, a growing calls for 'rethinking' contemporary approaches to doctoral education and research training have been made over the past decade in different national contexts, including North America (e.g. Nyquist & Woodford, 2000; McAlpine & Norton, 2006; Walker et al. 2007; Nerad, 2008; 2009), the UK (e.g. Roberts Review, 2002; Thrift, 2009) and Australia (e.g. Kemp, 1999; Harman, 2004; Manathunga et al., 2009; Cumming, 2010). Different forms of doctoral education have been evolving over the years in different national settings (e.g. Clark, 1993). The condition under which doctoral students are trained and integrated into the labour market varies in each national context. Traditionally, obtaining a PhD has been regarded as principally a preparation for an academic career, while significant number of PhD holders work in industry or outside the 'conventional S&E PhD occupations' (Lee et al., 2010), and the share of such doctorate holders varies (Enders, 2001; Lanciano-Morandat and Nohara, 2006). Universities are increasingly expected to produce doctoral graduates with the skills required by employers in various industrial as well as public and third sectors. However, this is paralleled with the "loss of exclusiveness as far as the role and centrality of higher education and the academic profession as the main source of new scientific knowledge and its dissemination" (Enders, 1999, p.73). There is also a growing need for universities to demonstrate the value of a doctoral education to individual students and prospective employers. Doctoral education and forms of research training are being shaped by a number of factors: the changing needs of society, of research modes (Gibbons et al., 1994); the changing nature of knowledge, academic profession and the university (Enders 1999; Geiger, 2004; Washburn, 2005), and growing university-industry relationships (D'Este and Patel, 2007; Beltramo et al. 2001). Stephen (2001) points out that technology transfer between university and industry have direct and indirect education implications for doctoral students and their research experiences. Nevertheless, empirical research with regard to the educational impact of university-industry relationships and implications for research training is in short supply (Chiang, 2011).

Some countries have developed national scheme to incentivise industrial engagement in doctorate training (Kitagawa, 2011). [2] This paper focuses on this UK Engineering Doctorate / Industrial Doctorate programme. In the UK, the Engineering Doctorate (EngD)

[2] For instance, in Denmark, an Industrial PhD programme has been established as "a three-year research project and research training programme with an industrial focus conducted jointly by a private company, an Industrial PhD student and a university" (The Danish Agency for Science, Technology and Innovation, 2009). The student is employed by the company, which can be a public sector organisation, and enrolled at the university. The programme is financed by the Danish Council for Technology and Innovation, and administrated by The Danish Agency for Science, Technology and Innovation. In France, Industrial Agreements for Training Through Research (CIFRE) is a programme to develop "public-private research partnerships based on theses jointly financed by firms and the National Association for Research and Technology (ANRT)". The CIFRE programme not only gives firms access to cutting-edge public research, but also helps the students to get a foothold in the firm in terms of their future job prospects. See Giret, J.-françois, & Recotillet, 2004.

programmes have been in existence since the early 1990s. The Engineering and Physical Sciences Research Council (EPSRC) has funded EngD Centres, which are recently called as the Industrial Doctorate Centres (IDCs). The Engineering Doctorate Scheme, one of the UK postgraduate degrees, was initially established by the Science and Engineering Research Council (SERC) in 1992, before the reorganisation of the research councils and the formation of the Engineering and Physical Sciences Research Council (EPSRC) in 1994. The aim of the Engineering Doctorate Scheme was to provide postgraduate engineers with “an intensive, broadly based, research programme incorporating a taught component, relevant to the needs of and undertaken through sponsorship with industry” (EPSRC, 2007). Distinguishing features of the scheme then was “its 4 year duration”, “higher stipend” than other doctorates, and a requirement for the students to spend a “significant amount of time on a project for their sponsoring organisation”. Those students who are enrolled on EngD degree are called ‘Research Engineers (REs)’, rather than ‘research students’. The programme is seen as a route to achieve “fast-track” progression to senior management positions in industry (Barnes and Neailey, 2011).

The chronological development of the programme is presented below, which is succinctly summarised in Box 1.

Box 1

1992 First 5 Engineering Doctorate Centres

1997 First Review; Another 5 Engineering Doctorate Centres

2001 Call for Engineering Doctorate Centres

2006 Call for Engineering Doctorate Centres

2008 New Centres for Doctoral Training (CDTs) - 45 Centres

2009 Industrial Doctorate Centres (IDCs) – 19 Centres

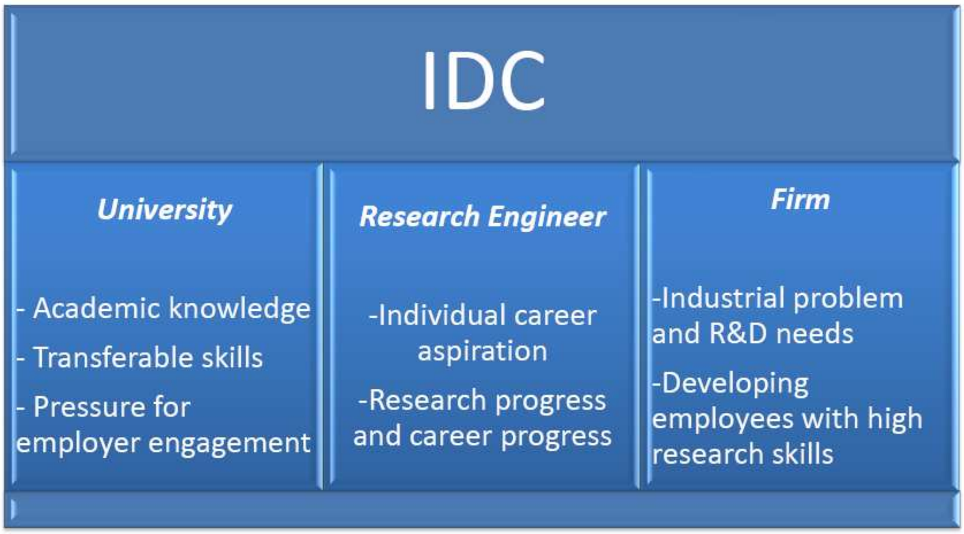
The Engineering Doctorate Scheme was launched with five Engineering Doctorate Centres in 1992, and the first review was conducted in 1997. Another five Centres were established after the first review. In 2001, 2006, following calls by EPSRC in “particular areas of identified national need,” further Engineering Doctorate Centres were created, sometimes as partnerships between several universities. Several earlier centres finished 5 year funding period, and some centres received continuing funding. In 2008 EPSRC opened new Centres for Doctoral Training (CDTs). CDTs provide a four-year doctoral training programme to a significant number of PhD students organised into cohorts. CDTs are partly similar to EngD as they provide 4 year doctorate programmes with taught courses rather than 3 year research only degree. Each Centre targets a specific area of research, and also emphasises transferable skills training. Initially the focus of CDTs was interdisciplinary research in strategic areas. While the relevance to industry and transferable skills are important element of the training, CDTs don't require students to spend time with industry. The £289 million was invested in 45 CDTs. This has resulted in a significant change in the landscape of engineering doctorate programmes in terms of the areas of programmes, training portfolio, and balance between support for career stages and research base programme (EPSRC, 2010).

Industrial Doctorate Centres (IDCs) were created in 2009 as a subset of EPSRC' Centres for Doctoral Training (CDTs). IDCs are considered to be "an evolution of the Engineering Doctorates Centres (EngD) scheme" operated by EPSRC since 1992. These 'user-oriented' Centres provide the same training environment and features as CDTs whilst also incorporating a strong industrial focus. As part of substantial expansion of the CDT scheme, in 2009 EPSRC decided to both "expand the scope of the previous EngD scheme (to cover the entire remit of EPSRC) and to seek to refresh the portfolio of Centres being supported (to allow new priority areas to be identified and supported - in energy for example)". Thus, the cohort of 19 IDCs represents "a mixture of new Centres and continuations (albeit in an evolved form) of a number of EngD Centres".[3] One of the new IDCs established in 2009 provides non-Engineering degree; therefore their degree is not called EngD (e.g. in the case of University of Oxford, it is called DPhil, like other doctorate degrees). In 2010, a new call is open to invite applications for EngD Centres in the area of manufacturing engineering, with a specific remit of the materials, mechanical and medical engineering programme.

IDCs are unique as doctorate students spend significant time of their programme within the industry. The IDC consists of three different 'stakeholders': the university research centre, the industrial research group and an individual industrial doctorate student, with different aims and purposes. Students carry out research project in line with the needs of industry, with rigorous academic quality of doctoral level. Schematically, the nature of the IDC can be presented in Figure 4 below.

[3] EPSRC Industrial Doctorate Centres http://www.epsrc.ac.uk/funding/students/coll/Pages/idc.aspx accessed 7 October 2010.

Figure 4 IDC as a compound of three different stakeholders with different agendas



In the case of Industrial Doctorate Centres (IDCs), the doctoral students, often called Research Engineers (REs), enrolled in Engineering Doctorate (EngD) instead of PhD, are not pursuing academic career in most of the cases. IDCs are designed to create ‘hybrid spaces’ for doctoral students to be placed in both industry and academic institutions, conducting research which is of relevance to the industry needs. Some of the REs are employed by the company, and they are sponsored by their own employers to complete EngD degree. Others start EnD degree, work as REs at the firms and often get employed after the programme. It is possible for them to pursue academic career afterwards, although this is rare. For them, the doctorate degree (EngD) is seen as academic as well as vocational qualifications, and in some cases.

Industrial Doctorates can be seen as an evolution of a doctoral programme to meet the new labour market conditions as well as a response to ‘multiplication of the links’ between the academic sector and the industrial R&D sector (Beltramo, et al. 2001). Firms need to solve industrial problems and need ‘state of the art’ scientific knowledge for their R&D needs. Firms also need to develop employees with high research and analytical skills. Individuals look for career progress, and those REs aspire research progress with industrial relevance. There are some financial incentives for firms to participate in IDC as it is relatively cheaper to have doctoral students supported by EPSRC. In order to ensure these agendas are shared, IDC management committees typically consist of mixture of academics and industrialists who have some projects with the university. They try to optimise training opportunities for doctorate students under IDCs.

4. Empirical Observations at the IDC in Systems as a case study : Research Methods and Initial Findings

A closer empirical investigation is conducted by looking at the recent development of Industrial Doctoral Centres (IDCs) funded by EPSRC. The empirical study has three specific objectives:

- To identify strategies of industrial actors involved in the IDCs as a form of 'employer engagement' to meet high level doctorate training and skills formation;
- To identify 'learning processes and strategies' of individual industrial doctorate students enrolled at the IDCs; and
- To identify strategies of academic staff developing the IDCs, and industrial partners working with the students.

The research was conducted through a mixed qualitative methodology: interviewing academic staff, participating in workshops with industrial doctorate students, a focus group meeting, and by carrying out a survey of industrial doctorate students asking their experiences of 'learning and skills formation' both at the university and industrial settings. This is an exploratory research, and methodologically there are a number of weaknesses. In this paper, some of the findings from the study conducted at one of the IDCs as a pilot case study are presented, and emerging issues identified through wider interviews are discussed. [4] The aim of the pilot study is to illustrate 'learning experiences' and 'strategies' of individual doctoral students who work between the two knowledge production systems and move across two spaces through their career building, namely academia and industry. The main purpose of this paper is to develop a conceptual framework to capture learning experiences of both

[4] An initial pilot study at the one of the IDCs was conducted between May 2010 – January 2011. The pilot study has been conducted at the IDC in Systems, in collaboration with the research and management team at the Systems Centre at the University of Bristol. The project took a mixed method qualitative research strategy including : attending a student focus group meeting and a workshop as an observer, interviewing academic staff, the IDC centre manager, a secondary documentary analysis and web based analysis of the IDC and sponsoring firms. These provided contextual information of the IDC in Systems. In order to gain systematic data sets on REs' attitudes and perceptions, an on-line survey with REs who are currently enrolled on the programme was developed and conducted. The survey was constructed in collaboration with the IDC research and management team. The on-line survey asks learning experiences and research strategies of REs while they are conducting industry focused and academically rigorous research project as well as taking taught components of the EngD programme. The survey targeting the REs was launched on 24 August and by 15 October, twenty five responses were collected out of the targeted fifty students (excluding the first year intake in October 2010). Interviews with other IDCs Centre managers or the Directors were conducted by telephone between August and September 2010. The on-line survey was circulated to students at four of the IDCs through the Centre managers or the Directors, which led to a small number of responses.

individual and organisations through the IDC, based on a small number of empirical observations.

Contexts of the Pilot Study

The IDC in Systems was originally established in 2006 as EngD in Systems between Universities of Bristol and Bath with £3.4 million funding from the EPSRC. A brief institutional context and development of the IDC in Systems is summarised below.[5] In the first three years, 31 EngD projects were established, across the full range of disciplines, sponsored by more than 20 different companies. In April 2009 the Centre was awarded a further £5.3million from EPSRC to establish a new Industrial Doctorate Centre (IDC) in Systems. The first year (2009-2010) of the IDC has brought on board a further 18 REs – the highest rate of recruitment across all IDCs in the UK (IDC in Systems, 2010).

The Engineering in Doctorate in Systems is for those who aspire to (IDC in Systems, 2010):

- Develop the knowledge and skills to become a leader in Systems
- Acquire excellent career prospects
- Join an international research network in Systems
- Gain experience of using the latest Systems techniques in industry sponsored research projects.

The taught component is delivered collaboratively by the University of Bristol and University of Bath. Research Engineers (REs) are registered at either University of Bristol or University of Bath, and they take same taught courses in the first year, while on average, they spend more than 70 percent of their time working at their companies. As of October 2010, the number of EngDs is 62: 80% is “stipend REs” who receive stipend from EPSRC (£15,000 a year), and 20% is “employed Res” sponsored by their companies. The fee for EngD degree (£7400 a year) is covered by the EPSRC.

The first cohort of EngD students started in 2006 under the Engineering Doctorate Centre in Systems. As of the end of 2010 when this study was conducted, the first cohort students are

[5] http://www.bris.ac.uk/eng-systems-centre/idc/about-idc/ accessed 30 September 2010

in their final year, and are due to complete their dissertation towards the end of 2010 and early 2011. One had already graduated in the summer of 2010.

There are currently 37 industry companies sponsoring the programme having stipend or employed REs, and there are a few firms that have both stipend and employed REs. 11 companies sponsor more than one RE. The nature of industry partners is diverse. One of the characteristics of the IDC in Systems is that the nature of the industry is very broad and it is not 'sector' specific, unlike many of the other IDCs. The industry sectors encompasses: nuclear, electronics, construction, service operation, renewable energy, built environment, defence, aero industry, and high tech manufacturing. The research themes REs are engaged at companies are identified as: "product/technology development" 41%; "sustainability" 21%; "decision support" 13%; Process development/organisational change 25% (IDC in Systems, 2010). The industrial sponsors vary in terms of size and experiences. There are large firms that take several REs while there are small and medium sized firms (SMEs) that work on a particular project with a RE. A view of a senior manager of a firm which is pro-actively engaged in the IDC, supporting strategic directions of the centre and benefiting from it is presented as follows (quote from IDC in Systems, 2010).

> *"We hoped that in addition to furthering his [RE's] professional education, we would meet other systems thinkers in other organisations, and identify opportunities to work together in new ways".*

Given the diversity of the firms and the sectors, it would be important to understand different needs and motivations of firms as well as issues and constraints they face through working with the IDC.

Results from Surveys with REs

The main empirical observation is based on 25 REs' responses to the survey, between August and October 2010. The results of the survey are presented in Figures in Annex. The following section gives an overview of qualitative empirical observations to highlight these points. Where appropriate, comments from the REs are quoted to highlight the diversity and complexity of their experiences, especially in terms of perceived challenges and "barriers" of knowledge exchanges across organisational boundaries. Understanding the perceived barriers to university-industry collaboration from individual's points of view is important because it uncovers the problems and challenges that have emerged in the processes of mobility experiences and knowledge exchanges. Qualitative study of personal experiences of REs illustrates such processes.

In terms of prior experiences, majority of the respondents answered that they had industrial experiences. 7 out of 25 respondents have been "Employed REs", employed by the same company prior to the enrolment of the EngD, which means they are supported by their current employer to engage in EngD, and have been already embedded in their industrial organisational contexts prior to the start. Another 9 REs have had experiencing of working at other companies – therefore they have had variety of industrial backgrounds. One respondent commented that he/she had been working in industry almost 20 years prior to starting the EngD. The remaining of respondents are REs more or less straight from their studies, but they answered that they had internship or other placement experiences within industry. In terms of academic experiences, the multiple answers show that many of the EngD students had had wider range of provisions such as management and leadership training, communication skills training and courses on entrepreneurship, those provisions genetically called 'transferable skills,' along with having studied academic courses related to EngD.

The relationship between gaining academic knowledge and applying the knowledge for industrial problem solving seems to be synergetic and dialectical process as the following comments illuminate:

> *"I benefit immensely from academic knowledge that I apply directly to my everyday work experience".*

> *"It's [being RE] unique in that I am solving a real industry problem that hasn't been solved before, and the results could be applied across the industry. If you are full time employed and not an RE, it is difficult to see and to solve problems in the organisation, but as an RE, you see the organisation with a third eye from an academic point of view, and you are better placed to see and solve problems (only if the managers can listen!)"*

There are comments from the respondents regarding the contexts of acquiring and practicing 'management and leadership skills'. The following two comments highlight different perceptions of 'industrial needs' and the level of individual autonomy and possibility of change organisational practices.

> *"I got more of this [leadership and management skills] than I expected. It's a good thing. It probably came from the freedom of the working environment and the opportunity to organise things off my own back. and in collaboration with the other REs."*

> *"The skills and basic knowledge [on management and leadership] are probably there, but no opportunity to practice, and the company doesn't seem to want any more leaders, just well trained followers..."*

Academic staff at the IDC in Systems had responded to the needs of the students, and taught programmes have been modified to reflect students' feedback. Given the fact that management and leadership skills are the areas of focus of the IDC in Systems, it is particularly interesting to investigate further in what ways EngD students see the changes in their skills and knowledge in management and leadership through the taught component of the programme, and in relation to their working and research experiences at the industry partners.

Another set of questions asked individual EngD students' strategies in carrying out research projects between academia and industry. "Which of the following factors do you think influence your strategies to carry out your research?" (Annex: Figure H). Individual and direct relationships with industrial and academic supervisors strongly influence students' research strategies. In particular, EngD students perceive the influence of industrial supervisor greater than academic one. The following comment from one of the respondents highlight the issues concerning the influence of the industrial supervisor and broader organisational context:

> *"Industrial supervisor was not made aware of the reason why senior management decided to go for the EngD. Also industrial supervisor is more focused on meeting short term objectives, he does not appreciate the length and benefits of research. He just needs to be educated on this"*

There are diverse perceptions about the extent of influence of other relational factors such as "existing collaboration between the company and the University" and "relationship with peers at the IDC". This may be areas where the IDC could be pro-active – how they create collaborative environments with industry partners; and how to make individual REs to create collaborative relationships which they can benefit for their industrial and academic achievements.

In response to the open question about the main challenges of being a RE, several comments point to the different needs between academia and business world and difficulty of balancing and managing these between two supervisors.

> *"Applying academic theory in a business setting is difficult. You have to show immediate financial return or the company is not interested."*
>
> *"Hard to keep academic and industrial needs balanced. Being able to fully express the problem as it keeps changing as the company changes".*
> *"Deciding what to prioritise, balancing the needs of the different supervisors, not getting stuck in a place where its hard to make progress"*

Sharing the value of research within the company is generally seen as challenge:

> *"Nobody is able to really understand the research you do, even your supervisors (unlike PhD). Makes you feel very alone, but also develops strong skills in resilience and independence"*
>
> *"Staying focussed on achieving an EngD award at the end of 4 years while being based in a company which has no one else with the same aims and therefore the focus of the work is very different in nature".*

Being a RE gives certain independence and autonomy of conducting research within an organisational setting, whilst whether or not the firm is ready to listen to the research results is another matter.

> *"Freedom of thought and ability to change direction of research aims and objectives. Implementation of findings is a different matter..."*

And to quote one of the REs again, being an RE is unique as it provides *"a third eye"* perspective, but whether or not the company respond to that perspective is not so straightforward (emphasis added):

> *"If you are full time employed and not an RE, it is difficult to see and to solve problems in the organisation, but as an RE, you see the organisation with a third eye from an academic point of view, and you are better placed to see and solve problems* ***(only if the managers can listen!)*** *"*

Several answers point out the difficulty of implementing the findings of research within the organisational culture.

> *"The main challenge is the organisational behaviour and culture is not, in my opinion, consistent with the research that I am carrying out: members of the board (and a lot of others in the company) do not want the changes that my research suggests we need."*

It seems that REs, in particular 'stipend REs' could see 'radical innovation' in organisations whereas employed REs may be better positioned to induce 'incremental innovation process, and if combined with their career strategies, it may lead to new leadership and innovation in organisational change.

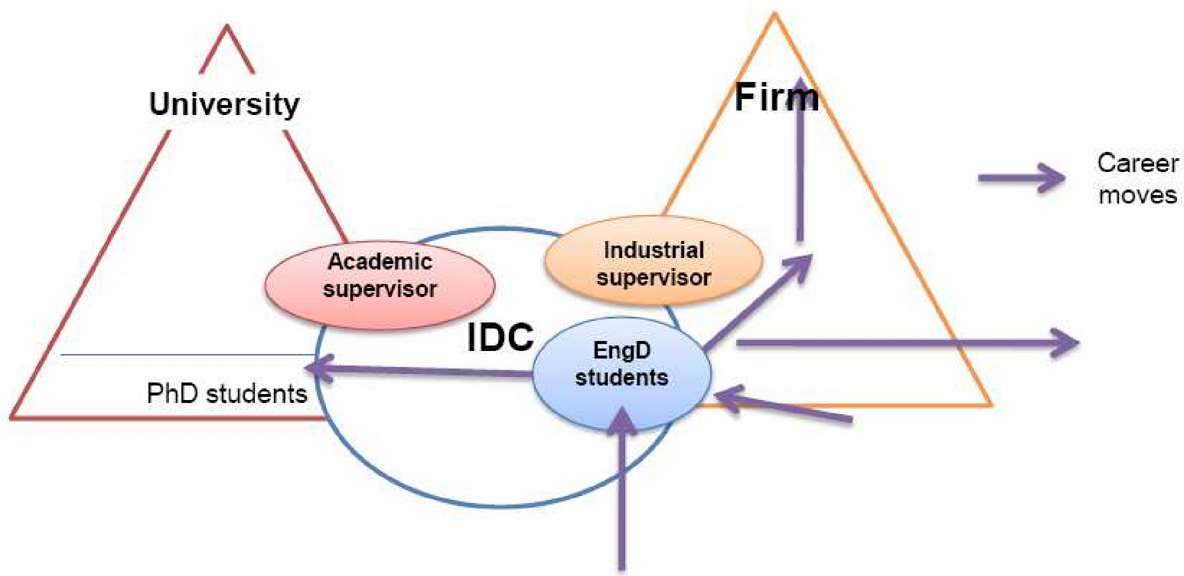
To the questions "What is your plan after the EngD, 18 REs answered that they want to stay at the same company where they work on EngD research. Out of seven employed REs that had worked at the same company prior to the EngD programme, six answered that they would stay. Many REs on stipend also express their expectation to stay at the company where they work on their project. In terms of career strategies, it should be noted that there are differences between those who are on 'stipend' and conduct research as EngD engineers at industrial partner companies, and those who had been employed at the company prior to the enrolment to the EngD programme. The differences between those REs employed by the firms and those on stipend were highlighted in the survey comments, and one of the IDC senior academics pointed out the issue. Those who had been employed are more embedded in their organisational contexts and obviously under higher pressure to meet the company needs at the work place.

5. Discussion: Issues concerning IDCs and employer engagement for doctoral training

The results of the survey with EngD students at IDC in Systems highlight some of the issues concerning employer engagement for doctoral research training and the complexity of the organisational contexts EngD students are embedded in. Some of the comments quoted above highlight complex nature of learning, power and identity within a workplace and throughout different stages of human capital development. Individual REs act as agents of knowledge exchange and competence building between the university and the firm, and furthermore, they sometimes act as agents of organisational changes within the firm. One of the issues which arises from the analysis of the survey concerns organisational change and the organisational structure of the EngD programme. An industrial doctoral student/RE stand in the middle of the two worlds – the university and the firm.

The career directions of Industrial doctorate students are diverse, as schematically presented below (Figure 5). Their career pathways cross-over not only academic-university boundary, but sometimes boundaries within the firms. In other words, REs work in different knowledge production systems, or "communities of practices" (Wenger, 1998) translating knowledge not only *between university and industry*, but also, their challenge is to translate different types of knowledge *within the firm* they work in with a limited freedom and autonomy. The constraints are amplified especially when they are not in a senior position. A senior academic staff at the IDC pointed out that whilst the firm top management level appreciate having a RE, the day to day manager, the industrial supervisor, may not necessarily share this strategic view. This resonates well with one of the comments from a RE in the survey as shown above. An agreement is made at the top level between the university and the firm, but that is not necessarily reflected in the work environment and research project where the RE is embedded in, and also, the context of work requirement changes rapidly.

Figure 5 Possible career directions for Engineering Doctorates



The survey with the REs at the IDC in Systems illustrates institutional complexity of working between "hybrid spaces", managing different expectations and solving industrial problems with academic inputs and support, as well as acting as 'change agents' within organisations. One of the industrial doctorate students described being a RE is:

> "*to gain a compromise between what the different stakeholders want from the project, i.e. me, my company, my industrial supervisor, the University*".

As already mentioned, there is a difference in terms of *autonomy* and *embeddedness* between EngD students who are on stipend and those who have been employed by the same companies prior to the EngD enrolment. Furthermore, the career perspectives for "linked scientists" in industry are not so straightforward. There are a number of perceived "barriers" between university and academia. In general, it is assumed that these barriers "hinder effective knowledge exchange". However, there is no evidence on "how the perceived barriers shape subsequent collaborations" (Bruneel et al., 2010) or how individuals may overcome such barriers. We do not know how these perceived barriers affect individual career strategies and decision making process.

The findings from the IDC in Systems may not be generalisable because of the nature of their programme – unlike other IDCs funded by the EPSRC, EngD in Systems has a broad spectrum of different types of industrial partners including nuclear, aerospace, high tech manufacturing, construction, defence, and service industry. Therefore individual REs have diverse range of experiences of sectors. Other IDCs have focus on specific industrial sectors, for instance, life science, nuclear engineering, or photonic technologies. EngD in Systems has another unique character as it takes broad 'systems approach' to problem solving encompassing engineering and social sciences, and staff at the IDC in Systems emphasises their strong focus on organisational management and leadership elements in the programme. Whether or not these programme characteristics, and the diversity of industry sectors, have effects on REs' perceptions and experiences need to be investigated by conducting a comparative study with other IDCs.

6. Concluding remarks

The model of IDCs and industrial doctorate students seem to be ideal for knowledge exchange. This correspond to the recent literature on the new scientific labour market - characterised by the formation of competences on a collaborative basis between academia and industry, through the creation of joint "pool of human resources" and the emergence of "linked scientists" (Lam, 2007). One of the IDC interviewees, a senior academic, illuminates this point:

> " *one of the best ways of achieving a good connection between two research groups, be they two academic, or an academic and an industrial one – is to have a person who is located in both, and these students fulfil that role*".

Industrial doctorate students who work between "hybrid spaces" of academia and industry can be seen as a new type of "linked scientists" who are likely to pursue industrial career rather than academic, though not exclusively. They are expected to become future managers-leaders of their organisations with agents of change with new scientific knowledge production as well as developing management and leadership skills.

Career development and workforce skill enhancement could provide long term incentives and sources of workplace innovation (OECD, 2010). Lepak and Snell talked about "hybrid mode of employment relationship that blends internationization and externalization" by developing partnerships with external organizations to create joint human capital (cited from Lam, 2007, p. 999). IDCs exemplify new spaces where "the joint production of new knowledge with commercial applications" occurs, and these spaces function as 'learning segment' as part of the intermediate labour market between academia and industry (Lanciano-Morandat and Nohara, 2006). However, 'hybrid occupational' segment part of the intermediate labour market is somewhat limited. There are a number of challenges related to "patterns of careers and incentives" as their career structure is not clear within the firm and throughout firms in a long term. As Lam (2007) points out, these challenges are underlined by "the divergent work norms and reward structures" governing the two different knowledge production systems between academia and industry. Further, their career perspectives and strategies are conditioned by many contingent factors within the firms, including their investment in scientific and technical human capital, and internal power structures.

This paper contributes to the current policy discussions on industrial engagement at higher education. Whether or not industry engagement with doctoral programme can be 'scaled-up' to a sustainable level in the long term is to be seen, and it would depend on the funding arrangement of the future higher education sector in the UK. At the institutional level, universities need to manage and balance different missions and activities – teaching, research and engagement with industry and society. Industrial engagement with doctoral provisions provides interesting questions regarding the relationship between these activities.

In the UK context, universities are facing different sets of policy expectations and agendas: the recent two policy agendas of “skills, learning and employer engagement” on one hand, and “industry links and knowledge transfer”, on the other, each represented by Leitch review (2006) and Lambert Review(2003), highlighted the industrial engagement activities as part of the missions of the university.

The accumulation of experiences of IDCs would be of value to the development of future provisions of similar kind in terms of linking scientific research training combined with human resource management and skill development at workplace at firm level. One of the biggest issues concerns incentives and constraints for employer engagement in doctoral education. Under the IDC, there are some financial incentives for firms to have REs. Once the relationship between the IDC and the firm is established, and once there is a trust between the two parties, there could be a virtuous cycle between the university, RE and the firm under the IDC model. Through these experiences both industrial and academic supervisors need to learn how to work together, because without learning, organisational changes and also culture change happening at both side, the employer engagement in doctoral education would not lead to hybrid space of learning.

Whether EngD or IDC provides new forms of doctoral training and new career pathway for non-academic doctorates remains a big question to be investigated further. Throughout its history, the number of EngD degree holders is already high and has an established credibility in engineering. The recent new development of Centres for Doctoral Training (CDTs) and new Industrial Doctorate Centres (IDCs) is still in early days, and too early to say specific impact of these. It would be interesting to compare other forms of PhD and industry related PhD, such as CASE studentship, and new provisions such as CDTs and IDCs and the career trajectories of those doctorate holders in the long terms. Another interesting comparative perspective would be to look at research training at doctorate level in different national systems of innovation and competence building. Countries such as the United States and the UK have developed highly deregulated labour markets combined with a number of university-industry links, whereas other countries have had more “hierarchical research system” (Lam, 2007, p.1014), often with greater roles played by public research institutes. The careers and training mechanisms for scientists and R&D personnel need to be investigated in such broader and diverse institutional landscapes from a comparative perspective. Such perspectives would open up debates concerning the convergence and divergence between different national systems.

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Annex

Figure A Year of the EngD programmes the respondents are registered

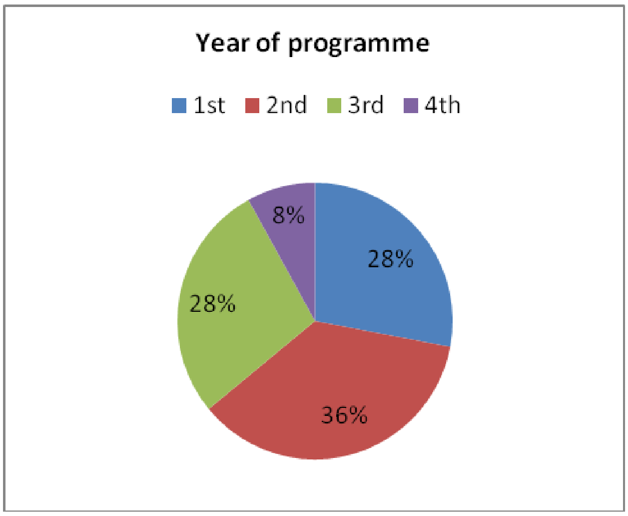

Figure B Prior Industrial Experiences

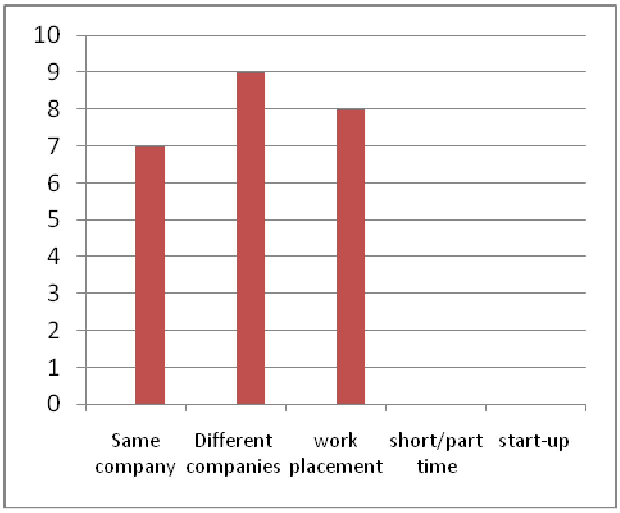

Figure C Prior Academic and training Experiences

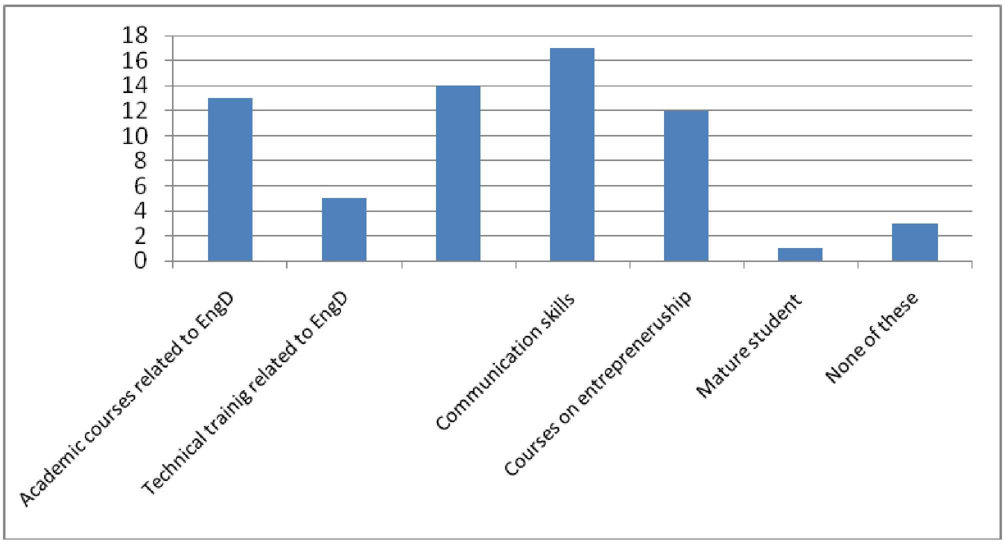

Figure D "What were/are your expectations as a result of completing the Industrial Doctorate?"

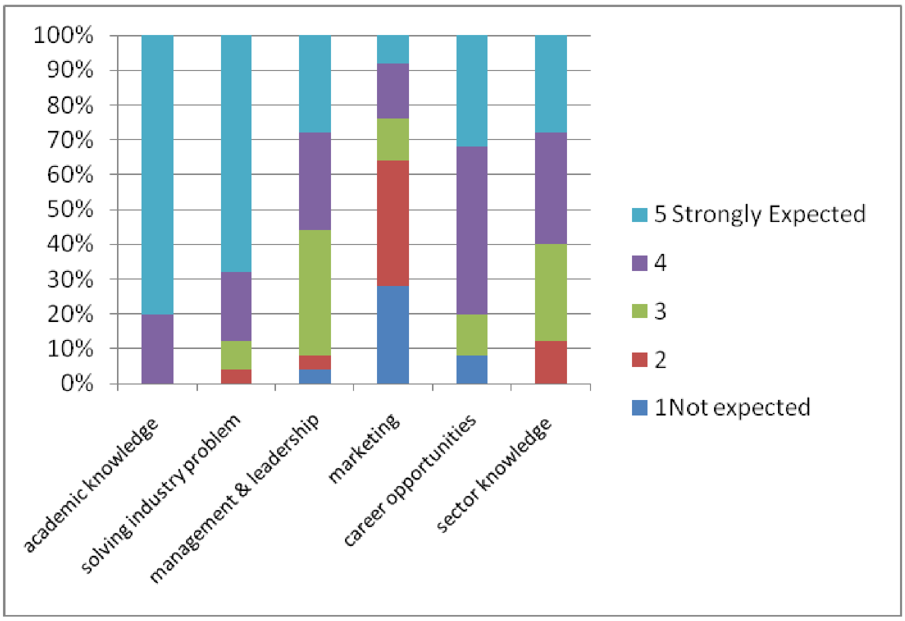

Figure E "To what extent have the above expectations been achieved so far?"

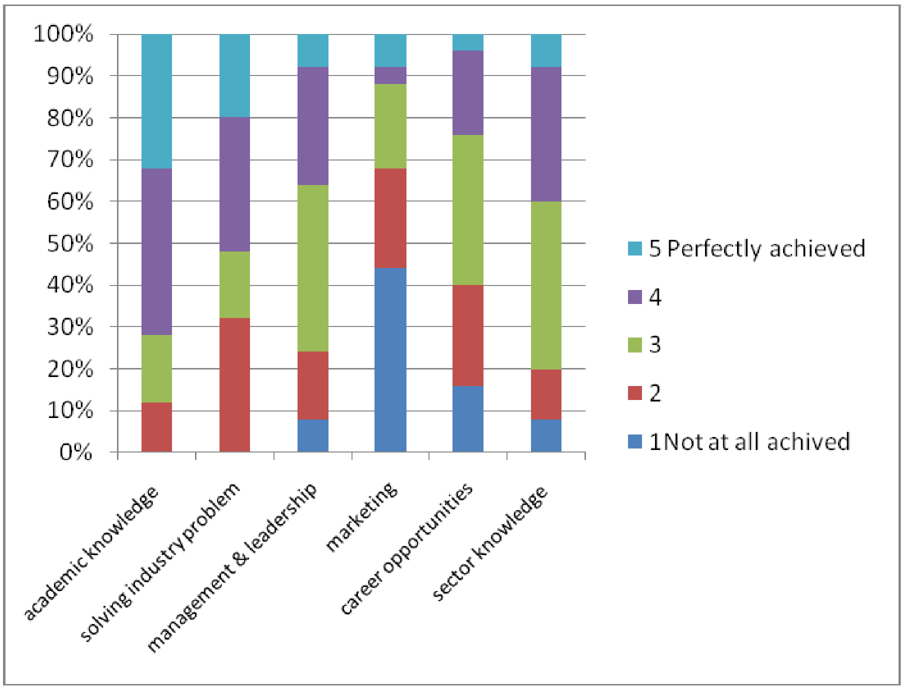

Figure F Changes in skills and knowledge through "taught component" of the EngD programme

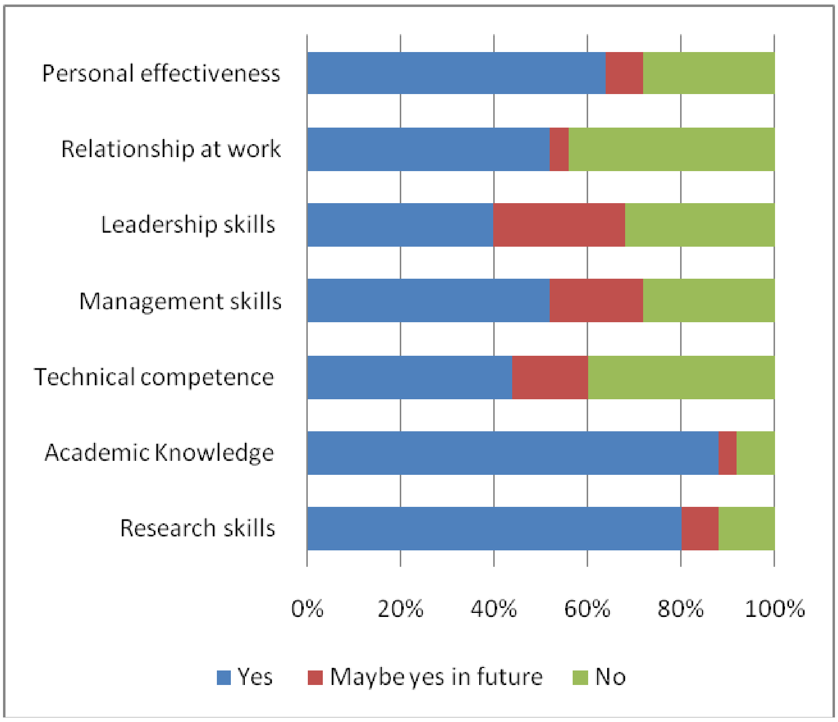

Figure G Changes in skills and knowledge through working and conducting research within industry

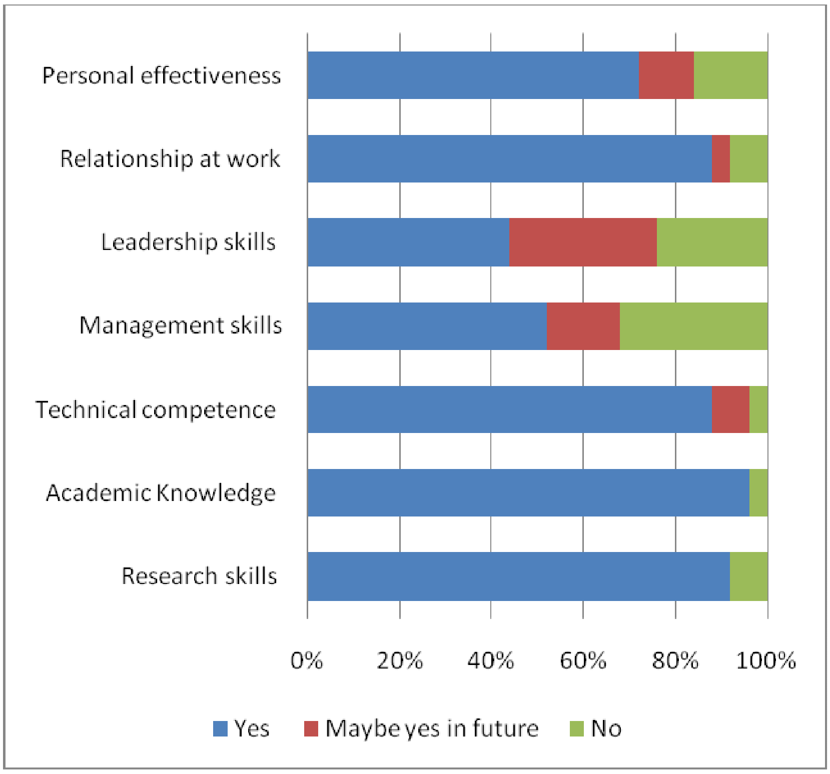

Figure H Factors affecting EngD students' research strategies

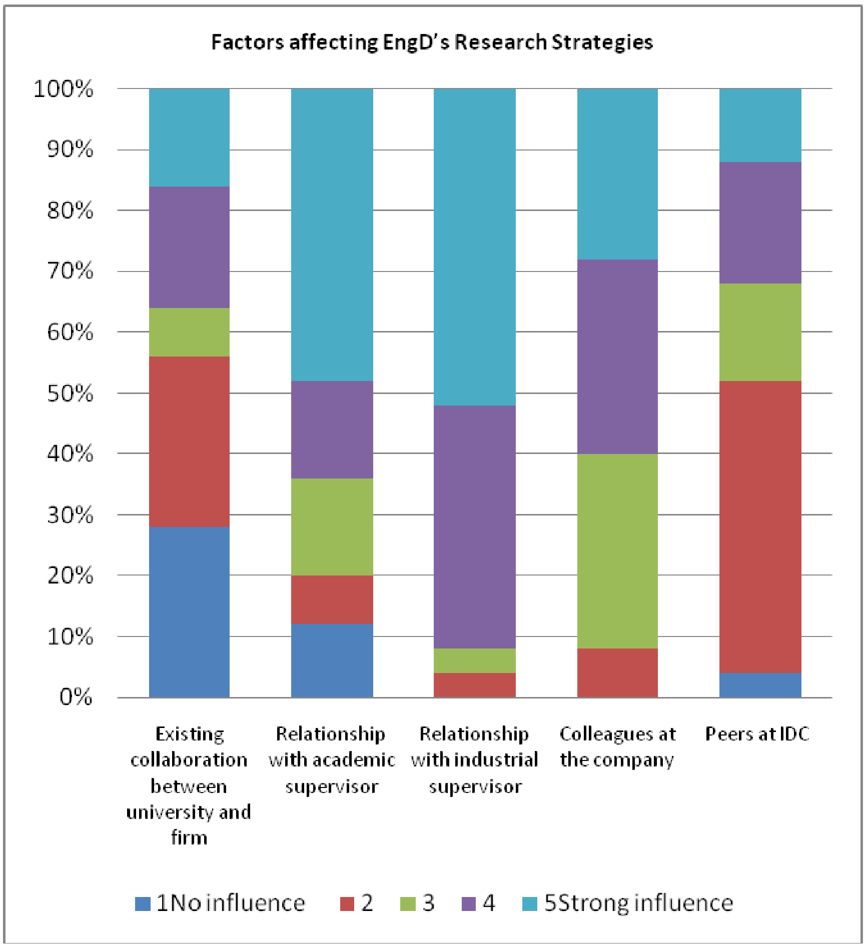

Figure I Perceived Impacts through EngD to the company

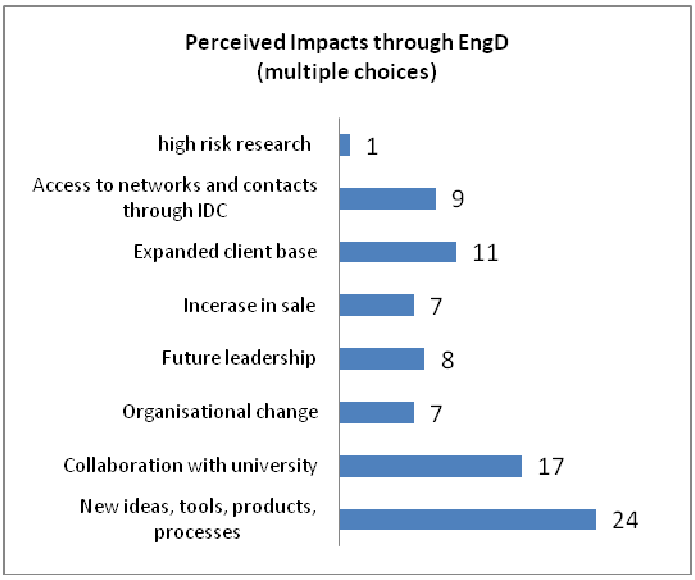

Figure J Future Plans of EngD students (multiple choices)