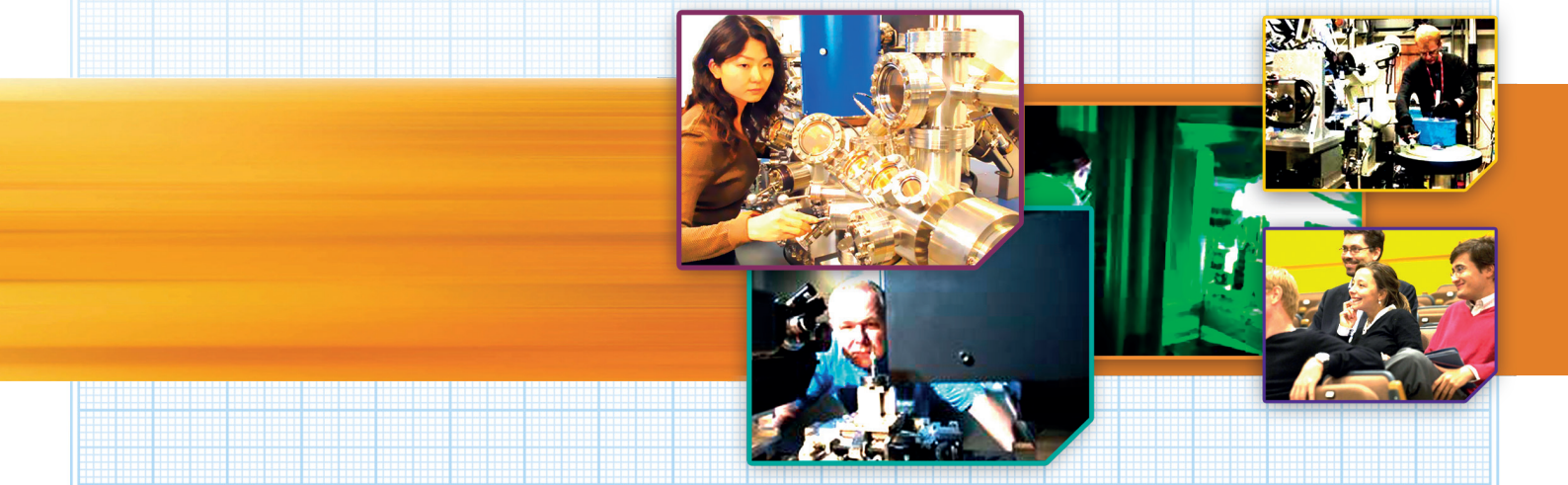
EPSRC
Engineering and Physical Sciences Research Council

AEngD Association of Engineering Doctorates

UNDERSTANDING THE ENGD IMPACT

A Pilot study



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Understanding the EngD Impact –

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List of Abbreviations

AEngD	Association of the Engineering Doctorates
BIS	Department for Business, Innovation and Skills
CASE	Collaborative Awards in Science and Engineering
CBI	Confederation of British Industry
CDTs	Centres for Doctoral Training
CPD	Continuing professional development
DLHE	Destinations of Leavers of Higher Education
DTI	Department for Trade and Industry
EngD	Engineering Doctorate
EPSRC	Engineering and Physical Sciences Research Council
EUA	European University Association
GDP	Gross Domestic Products
GVA	Gross Value Added
HEI	Higher Education Institution
HESA	Higher Education Statistical Agency
ICARG	Intercompany Academic Relations Working Group
IDC	Industrial Doctorate Centre – a type of CDT emerging from EngD centres
IMRCs	Innovative Manufacturing Research Centres
KTP	Knowledge Transfer Partnership
NSF	National Science Foundation
PGR	Postgraduate Research
R&D	Research and Development
RE	Research Engineer
SME	Small and Medium sized enterprise

Executive summary

This study aims to understand the impact of the Engineering Doctorate (EngD) programmes provided by the Engineering Doctorate (EngD) Centres and the more recently established Industrial Doctorate Centres (IDCs). The project set out as a short-term pilot study (March-October 2013) and was sponsored and supported by the Association of the Engineering Doctorates (AEngD) and the Engineering and Physical Sciences Research Council (EPSRC).

The primary target of the study is to understand the **impact of the EngD** with specific focus on:

1) **impact on industry partners** - providing evidence of the value of EngD project sponsorship to industry
2) **career pathways** - identifying how the EngD experience shapes the career paths of EngD graduates (EngD Alumni)

This pilot study was designed to provide a review and analysis of accumulated evidence from published sources (see Section 4), supplemented by additional data (e.g. information collated from the Centres for Doctoral Training, CDT, mid-term review, which included IDCs; stakeholder interviews), in order to develop and propose frameworks to better understand and to evaluate the EngD impact. Given the exploratory nature as a pilot study, the work aims to identify and assess various sources of data and the value of different types of enquiry methodologies. This study does not intend to provide a tool that will measure the performance of the EngD scheme in terms of overall economic and societal impacts. However, where possible, it aims to suggest possible impact indicators.

The main report contains a summary of key findings, lessons learned and recommendations for a future study. In the Annex, detailed findings are presented which form the evidence base for the main report. Where there is weak or limited evidence, this is highlighted in the text, and recommendations are made for a possible future study. The remainder of this report is structured as follows:

- Section 2 sets out the conceptual framework to understand the impact from collaborative research and training, drawing on recent studies on impacts.
- Section 3 explains the research design and enquiry methodologies developed to capture the impact of the EngD programme, sources of data and the limits of the study.
- Section 4 presents the background of the EngD scheme, existing data and review on its impacts.
- Section 5 presents key findings from the study and discusses the different routes to impact in relation to both industry and alumni.
- Section 6 sets out conclusions and recommendations.

A number of supplementary data-sets and evidence as well as background information are presented in the Annex. These include the findings from the 18 IDCs mid-term review reports; data from the semi-structured telephone interviews with the EngD alumni and Industry contacts; and the initial analysis of the HESA Destinations of the Leavers of Higher Education (DLHE) data presenting the EngD graduates' destinations six months after graduation, 2008/9-2010/11.

For the purpose of this study, the interviews were conducted with those who have direct experiences of the EngD programmes. It should be noted that the perceptions of the impacts gained in the interviews may

have some biases. Whilst the data-sets collected in the interviews were relatively small, efforts were made to include the diversity of the contexts to be represented in the study – industry sectors and different types of IDCs across the UK.

- For the RE (Research Engineer) alumni (20 individuals interviewed), collected data represents alumni from different IDC/EngD Centres, with different industrial experiences prior to undertaking the EngD, and a variety of career paths after the EngD. The sample group is diverse in terms of industry sectors, where EngD alumni are employed, as well as in terms of demographic features such as age and gender.
- For industry contacts (15 individuals across 11 industry sectors), in addition to the contacts made through the IDCs, the research team made direct contacts with individual firms with repeated experiences of EngD projects and programmes (see EPSRC, 2007 Annex).

Background information about the current sponsoring firms was collated from the existing 20 IDC websites. Further profiles of the EngD alumni were provided by analysing recent HESA DLHE data (125 EngD graduates identified in 2008/9-2010/11 cohorts).

The EngD scheme constitutes a form of academia-industry collaboration, which not only generates new knowledge but also enhances knowledge exchange between industry/business and the university. The EngD programmes enhance human capital development by producing people with skills including leadership and management, as well as technical skills.

Broadly, **four routes to the impact** from the EngD programme were identified:

- *Generation of new knowledge*
- *Innovation*
- *Knowledge networks and collaboration*
- *Human capital and skills development*.

- **Generation of new knowledge**

New knowledge from the EngD projects leads to increased in-house knowledge and research outcomes in the short/mid-term, as well as a long-term approach to technology problem solution and business change. Standard formation and policy change based on knowledge generated from the EngD projects are long-term routes to impacts, leading to sector-wide and/or broad social change.

- **Innovation-related routes to impact**

Outputs include patents, new technology, new processes from the EngD projects. Outcomes include commercialisation of the EngD outputs via *licensing* of patents, formation of *spin-out companies*; *new product/service development*; *new market entry*; *improvements to business processes* and *accelerating time to market*. Innovation related outcomes may lead to *cost savings* and wider *economic impact*.

- **Knowledge networks and collaboration**

Knowledge generated by one firm often diffuses into the industry as a whole through *collaborative relationships*, through *supply chains* or through *movement of human capital*.

- **Human capital and skills development**

Three forms of impact routes are identified:
1) individual RE career path developments;
2) organisational absorptive capacity development at the industry partner level through enhanced skills development; and
3) sector-wide impacts by creating a pool of highly skilled talents and future leaders.

The impacts of the EngD are found at individual, organisational and sector levels, brought by the multiple levels of inputs and activities through the EngD programmes at IDCs and through individual EngD projects. The IDCs act as a hub for the impact routes, some of which lead to direct economic benefits and impact. Assessing the economic impact is one way of understanding the EngD impact.

One of the unique characteristics of the impact of the EngD scheme derives from interactive relationships built between academia and industry, and the tacit nature of the knowledge flows across organisations. This provides the key challenge in measuring and evidencing the impact of the scheme over the years.

Key factors that condition the EngD impacts were identified as follows:

- *RE's individual factors* (e.g. age, gender, industry experiences);
- *characteristics of the EngD projects* including the nature of the technology, such as technological specificity, 'technology readiness level', areas of scientific disciplines;
- *the academic environment and organisational factors*, including the history and characteristics of the IDC/EngD Centre;
- *the nature of the sponsoring firm and the sector*, including firms' hiring decisions, culture and policies towards promotion, as well as organisational strategies of the sponsoring firm.
- *broader social and institutional conditions,* including the labour market conditions, corporate governance structures and R&D investment in the scientific fields.

Key recommendations based on the mid-term review analysis, interviews with industry partners and EngD alumni, and the HESA DLHE analysis are follows:

- The IDCs/EngD Centres work with a range of different industry partners including large firms, SMEs and start-up companies. The nature and diversity of industry partners – existing and potential ones – has to be better understood, including their motivations, R&D and skills needs and perceived barriers for collaboration.
- A further study is needed to collect a broad evidence-base on different forms of impacts, in relation to the nature and objectives of the projects, and the strategies of the industry partners and the industry sector.
- A strategic monitoring approach and support to the RE by the sponsoring firm would help better capture and roll-out the outcomes of the EngD project during the programme. A broader impact of the EngD programme through *supply chain relationships* needs further investigation.
- Career development and pathways of the former REs are diverse and need more data sets and comparative analyses. Destinations and the career pathways of the EngD graduates need to be more systematically collected across the IDCs. This study does not compare EngD impacts with other forms of doctoral training. Comparative data of the EngD graduates with other doctorates and with those working in industry without doctoral experiences would be of value in understanding the nature and impact of different types of doctoral research training.
- A careful methodological approach is required for the economic impact analysis. A few IDCs provided their economic impact estimation in the mid-term review reports. More coherent methodological guidance and systematic approaches to the data collection would help better evidence the impact of the IDCs.
- The EngD needs to be understood as part of the broad portfolio of R&D activities and skills. Different centre types and doctoral programmes complement the R&D activities across the industry sectors covering different scopes of technology and different types of skills needed for the future leadership and technical research in industry.

Acknowledgements

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1. Introduction - Objectives and scope of the study

The Engineering Doctorate (EngD) scheme was established over 20 years ago, following the Parnaby report (1990), which led to a change in the approaches to doctoral training and education (Powell, 2012). The Parnaby report saw the need for a major new scheme to provide Engineering Doctorate (EngD) programmes in the processes and practices of engineering, required by industry. It concluded that such an Engineering Doctorate would be distinct from, and complementary to, the traditional existing PhD, which has been criticised for its lack of industrial relevance (Parnaby, 1990; Godfrey, 2012).

Similar to the PhD, the EngD is a postgraduate research (PGR) programme. It differs from a traditional academia-based PhD in that it expects PGR students (Research Engineers: REs) to work on projects which are industry-based. This positioning of EngD in industry provides REs with industry relevant skills, as well as industry based research experiences. The EPSRC Review in 2007 found that the EngD programmes were meeting real business needs, many of the REs are having "a major impact on business performance" and that the scheme was making a valuable contribution to UK knowledge generation and transfer into industry, while satisfying its goals in terms of scholarships and publications (EPSRC, 2007). In 2009, 19 Industrial Doctorate Centres (IDCs) were created as a subset of EPSRC's new Centres for Doctoral Training (CDTs). The IDCs are seen as a development of EPSRC's EngD Centres. As of 2011/2012, £19 million was invested in 29 IDCs, the number of EngD students trained at IDCs amounted to about 1400 and the number of company partners under the scheme amounted to some 600 over the previoust 20 years (Golby, 2012).

In this study, the following distinctions are made:

- **EngD scheme** is the EPSRC-funded and industry sponsored venture to establish a number of EngD programmes at the former EngD Centres and more recent IDCs in the UK, in accordance with recommendations in the Parnaby report;
- **EngD programme** is a four year postgraduate research programme in the UK higher education institutions, consisting of a combination of taught and research elements and skills development and training for industry. The graduates from the EngD programme are awarded with the EngD degree.

This study aims to understand the impact of the EngD programmes provided by the EngD Centres and the more recently established Industrial Doctorate Centres (IDCs). The project was set out as a small-scale pilot study (March-October 2013) and was sponsored and supported by the Association of the Engineering Doctorates (AEngD) and the Engineering and Physical Sciences Research Council (EPSRC).

The key objective of this study is to define and understand what the 'impact' of EngDs is and to identify how it can be best evidenced. It starts by asking the question: "What is the nature of EngD impact?" Whilst the benefits and unique characteristics of the EngD programmes are recognised and acknowledged by industry, academia and government, there is a need to build an evidence base to demonstrate the accumulative value of these programmes and to understand what works and what does not work. Such an evidence base would be able to support the future advancement of the scheme, and enable better understanding of the mechanisms that roll out the impacts of the EngD encompassing a wide range of stakeholders in various contexts.

Building on the conceptual frameworks developed for the "Study on the economic impact of the Research Councils" (PA Consulting Group/SQW Consulting, 2007) and adopting the methodological approaches

developed for “The Economic Impact Study of Innovative Manufacturing Research Centres (IMRCs)” (DTZ/EPSRC, 2011), this study examines various forms of EngD impact.

The main focuses of the study are on:

1) **impact on industry partners,** providing evidence of the value of EngD project sponsorship to industry, and

2) **career pathways**, identifying how the EngD experience shapes the career paths of EngD graduates (EngD Alumni)

First, we identify and examine tangible data-sets and intangible processes involved in the EngD programmes. The study reviews existing published reports on the EngD scheme (e.g. Strategic Marketing Associates, 2006; EPSRC, 2007) and recent evidence (the EPSRC CDTmid-term review, 2011), and generates additional new data through stakeholder interviews. For the purpose of this study, the interviews were conducted with those who have direct experiences of the EngD programmes including industry partners and EngD alumni. Where possible, the research team attempted to triangulate the interview findings given that the perceptions of the impacts gained in the interviews may have some biases.

Key findings of data analysis are used to develop and propose the impact frameworks and to enhance our understanding and characterisation of the EngD impact. Given the exploratory nature of this pilot study, this work aims to identify and assess various sources of data and enquiry methodologies, and aims to establish impact indicators. However, it does not intend to provide a tool that will assess the performance of the overall EngD scheme in terms of economic and societal benefits.

The main report contains a summary of key findings, lessons learned and recommendations for a future study. In the Annex, detailed findings are presented which form the evidence base for the main report. Where there is weak or limited evidence, this is highlighted in the text, and recommendations are made for a future study.

The remainder of this report is structured as follows:

- Section 2 sets out the conceptual framework to understand the impact from academic research and training, drawing on recent studies on impacts.
- Section 3 explains the research design and enquiry methodologies developed to capture the impact of the EngD, sources of data and the limits of the study.
- Section 4 presents the background of the EngD scheme, existing data and review on its impacts.
- Section 5 presents key findings from the study and discusses the different routes to impact in relation to both industry and alumni.
- Section 6 sets out conclusions and recommendations.

A number of supplementary data-sets and evidence as well as background information are presented in the Annex:

1. 18 IDCs mid-term review reports
2. Telephone survey questionnaires for RE alumni and industry contacts
    - List of interviewees (anonymised, by types, roles and by industry)
    - Key themes, findings and quotes from interviews

- Case studies of the EngD alumni
- Interview questionnaires

3. HESA Destinations of the Leavers of Higher Education data summary (2008/9-2010/11)
4. Exploratory snapshot of networks of the 2009 IDC and sponsoring companies
5. Collaborative industry doctoral programmes –international perspectives

2. Capturing impacts from collaborative research and training

A growing number of studies focus on the importance of 'impact' from academic research and training, looking into the frameworks of impact and methods of evaluation (e.g. RCUK, 2010; Vitae, 2008; 2012). According to the RCUK report "Excellence with Impact" (2010), research could make economic and societal impacts, if the knowledge that it provides will "benefit not only individuals, but the organisations and the nations." In recent years, the economic recession has enhanced policy focus on issues of value-for-money and the impact and benefit from academic research for society and the economy, including the "added value" of recruiting highly qualified graduates (e.g. a PhD) (CIHE, 2009). Concerns have been raised about the PhD graduates' employability – the adequacy of doctoral graduates in terms of meeting the skills needs of employers. In addition, a pertinent question has been asked about how well academic excellence is aligned with societal needs and relevance.

The analytical frameworks and possible methodologies to identify actual evidence of impact are diverse, depending on the nature, scope and range of 'impacts' in specific policy contexts (see de Campos, 2010; Salter and Martin, 2001). Government and the public bodies are trying to identify the ways in which the effectiveness of public measures can be assessed and evaluated (see HM Treasury, 2003). In 2007, the DTI published a paper "Measuring economic impacts of investment in the research base and innovation – a new framework for measurement," in which economic impacts are defined – ranging from those that are "readily quantifiable, in terms of greater wealth, cheaper prices and more revenue", to those "less easily quantifiable, such as effects on the environment, public health and quality of life" (DTI, 2007).

The evaluation methodologies range from pure quantitative, pure qualitative and mixed techniques. There have been a number of recent studies to quantify and measure the impact of collaborative research programmes based on certain tangible outputs or outcomes. The indicators include knowledge production measured by the number of peer reviewed publications, research capacity building measured by the number of students trained, networks and interactions, policy or product development and wider economic and societal benefits, including increased productivity and GDP growth. For example, a recent impact study of mathematical sciences commissioned by the EPSRC presents economic impacts, including direct impacts on GVA, indirect and induced effects as well as wider impacts and benefits (Deloitte, 2012).

In particular, two of the economic impact studies commissioned by the research councils are of relevance to this study in terms of their conceptual frameworks and methodological approaches. The "Study on the economic impact of the Research Councils" (PA Consulting Group/SQW Consulting, 2007) provides conceptual and methodological frameworks to understand the impact arising from research. "The Economic Impact Study of Innovative Manufacturing Research Centres (IMRCs)" (DTZ/EPSRC, 2011) not only provides evidence on "economic impact" but also demonstrates "the added value" of the centres. Furthermore the study identifies "different pathways to impact", drawing on the case studies of 15 IMRCs.

The conceptual frameworks and methodological approaches adopted in this pilot study are not directly based on the above mentioned two impact studies. However, to be consistent with the current impact evaluation frameworks, where possible, relevant frameworks and methodological approaches are referred to and applied. For example, whilst it is not the primary aim of this pilot study to provide the overall economic and social impacts of the EngD scheme, the economic impact assessment framework developed in the IMRC impact study is adopted in order to better understand the EngD impact.

The economic impact assessment framework developed as part of the IMRC study is presented in **Figure 1** below.

Figure 1: The economic impact assessment framework (DTZ/EPSRC, 2011)

There are other literature and evaluation reports published in the past 20 years that this study could draw on. Key findings from the studies on impact from academic research and research training can be summarised as follows:

- A number of routes from research to impact come through *innovation processes*.
- Impact from academic research and research training occur through the *movement of skilled researchers* into industry or to other research organisations.
- In terms of human capital development, there are *different types of skills and knowledge* formed as an outcome of university-industry sponsored collaborative R&D and training schemes.
- *Networks and linkages* are catalysed by the university-industry sponsored collaborative schemes.
- Research impact may occur due to the *behavioural changes*.

Some of the key literature under the themes identified above is presented in Table 1 below.

Table 1: Impacts from research and training – summary of literature

Innovation-related impact	A number of routes from research to impact come through "innovation processes" as part of a broader R&D collaborative environment (PA Consulting Group/SQW Consulting, 2007).
	Innovation processes are influenced by broader R&D environments, including demand for innovation, knowledge exchange efficiency and other framework conditions (DTI, 2007).
	It is pointed out that often major breakthroughs in innovation in such collaborative partnerships occur from some of the most informal interactions, and capturing these interactions is often the most difficult part of measuring impact and outcomes (CBI, 2010).
People-based partnership scheme and spill-over effects from the collaborative relationships	People-based partnership schemes including the EngD and the CASE studentship/Industrial CASE focuses on the use of doctoral students as "agents of change," who are able to realise the benefits of cooperation, hence, creating spill-over effects from the collaborative relationships (Butcher and Jeffrey, 2007).
	Graduates and doctorates act as *knowledge networks* between public and private sectors – "raising absorptive capacity and assisting the dissemination and deployment of research results" (PA Consulting Group/ SQW Consulting, 2007).
	Such networks are actively promoted by the Research Council through different collaborative doctoral schemes (Demeritt and Lees, 2005). There are other collaborative schemes such as Knowledge Transfer Partnerships (KTP) (Gertner et al., 2010; CIHE, 2012), which could be combined with a PhD study.
Skills development and future S&T leaders	Graduates bring into industry an "attitude of the mind" and a "tacit ability" to acquire and use knowledge in useful new ways. Such abilities are highly valued by industry (Senker, 1995).
	Specific knowledge of recent research training and techniques are complemented by more generic skills; the ability to solve complex problems, the skills to perform research and the ability to develop new ideas (Martin & Tang, 2007). It is reported that employers value those with STEM skills, not only for their subject specific knowledge, but for their wider knowledge base (DIUS, 2009).
	These students and researchers enhance the capacity for "problem–solving" - through "knowledge manipulation and analytical skills enhanced through graduate training" (PA Consulting/ SQW Consulting, 2007). Analytical problem-solving is a desirable skill which is recognised by business communities (Demeritt and Lees, 2005).
	Training and developing *the next generation of science and technology leaders* is also recognised as the impact of such schemes, where doctoral engineers work at the frontiers of "innovation, substantial and varied industry problem-solving experiences, and insights into future challenges (and opportunities)" (O'Sullivan, 2011).
Behavioural changes	Research impact may occur due to the behavioural changes, so-called *behavioural additionality*, rather than stimulating additional research inputs (input additionality) and associated increases in research outputs (output additionality) (Buisseret et al., 1995).

The EngD scheme constitutes a form of people-based university-industry collaborative scheme, which not only generates new knowledge but also enhances knowledge exchange between industry/business and the university, and trains people with a broad range of skills, including leadership, people management, change management, as well as expert technical skills – leading to highly skilled human capital development.

As stated in Section 1, the objective of this pilot study is to better understand the EngD impact within the diverse and specific contexts of the programmes and each of the projects. In particular, the focus is on the specific forms of impacts on an individual level – EngD graduates, and organisational and sector levels as perceived by the industry partners.

Broadly, four key areas of activities are identified as routes to impacts from the EngD programme:

- Generation of new knowledge
- Innovation
- Knowledge networks and collaboration
- Human capital and skills development.

In this study, the route to impact is conceptualised to include *short-term* direct outputs and *mid-long* term outcomes from the programme. Impacts may include unintended and unexpected outcomes, behaviour changes, which are sometimes long-term and intangible in nature, and also, changes in policies and industry practices.

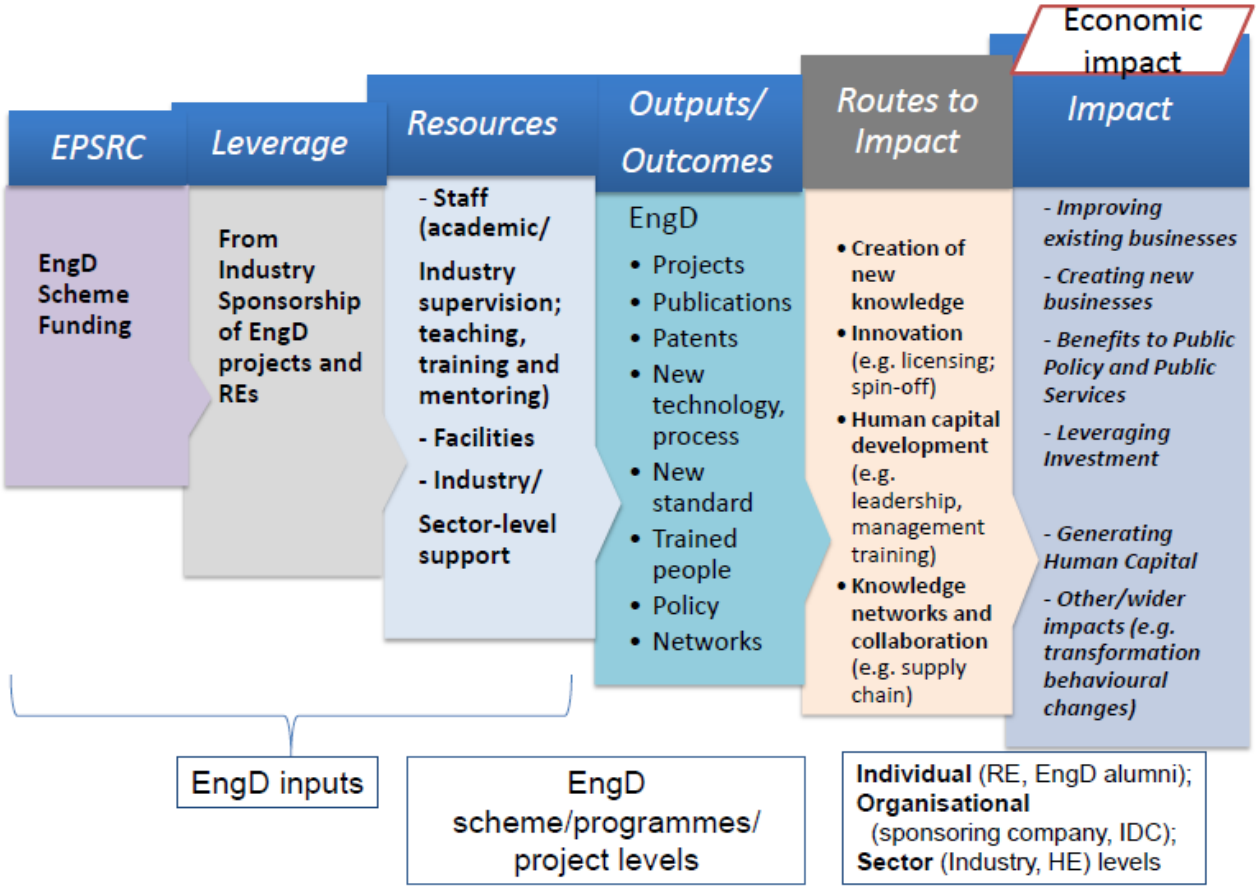
The impact categories used by BIS and EPSRC and adopted in the IMRC study (DTZ/EPSRC, 2011) have the following headings:

- Improving existing businesses
- Creating new businesses
- Benefits to public policy and public services
- Leveraging investment
- Generating human capital
- Other/wider impacts

Synthesising the review of literature, and drawing on the initial mapping of impacts through the IDC mid-term review (see Section 3), the EngD routes to impact framework was developed building on the framework developed by the IMRC study.

Figure 2 illustrates the routes from EngD inputs, outputs, outcomes and routes to impacts at the EngD scheme level.

Figure 2 The EngD/IDC routes to impact framework (developed from the framework by DTZ/EPSRC, 2011)



The impact of the EngD is found at individual, organisational and sector levels, brought by the multiple levels of inputs and activities through the EngD programmes at IDCs and individual EngD projects.
As a "people-based partnership" scheme, one of the unique characteristics of the impact of the EngD scheme derives from interactive relationships built between academia and industry, and the tacit nature of the knowledge flows across organisations. This provides the key challenge in measuring and evidencing the impact of the scheme over the years. Assessing the economic impact is one way of understanding the EngD impact. A broader range of routes to and forms of impact is captured in the rest of this report.

3. Investigation and enquiry methodologies

The project team was led by Dr Fumi Kitagawa at Manchester Business School and empirical data was collected with a group of five Master's students enrolled in the Global MBus Analysis programme. In order to ensure the quality of the study, the EngD Impact Study AEngD steering committee sub-group was formed in January 2013, including representatives from 4 IDCs. The research team consulted this sub-group as well as a representative from the EPSRC about the design and implementation of the study. As a result of this consultation, it was agreed that the study would primarily focus on building conceptual frameworks with a view to understanding and characterising the EngD impact. Overall, the methodology of the study consisted of several stages as follows:

- Consultation with the AEngD and EPSRC
- Review of existing data on the EngD/IDCs and broader impact studies
- Review of the 18 IDCs mid-term review reports
- Development of the "routes to the impact" framework
- Consultation with the AEngD, EPSRC and IDCs representatives to gather the evidence
- Collating new data via telephone semi-structured interviews
- Communication with the HESA and EPSRC on Destinations of Leavers of Higher Education (DLHE) data
- Data analysis and writing up the report and the Annex

A careful methodological approach is required in assessing the impact of the scheme. After consulting the AEngD and EPSRC, and agreeing on the scope of the pilot study, the initial desk top study was conducted in order to identify gaps in existing knowledge and to develop a logic model as an initial conceptual framework. A mapping exercise was conducted based on the CDT *mid-term review* which included 18 IDCs that were submitted to the EPSRC in May 2011 from the 19 IDCs funded in 2009 (one non-AEngD member IDC was not included in this study). These were made available for this study by the EPSRC following consent from the AEngD centre members. The mid-term review gave a useful overview of the self-perceived impacts of the IDCs. However, limitations of the data were noted in terms of the consistency and comparability across the IDCs (see **Annex 1**).

The data collection was carried out between April and August 2013. This was done by collecting a small scale of data, as opposed to gathering a large-scale data-set. The main research strategy adopted in this study is a qualitative one. The key information collected relates to attitudes and perceptions of individuals with the EngD experiences, based on a limited number of telephone interviews. There are two targeted stakeholders in terms of understanding the impact of the collaborative doctoral programmes - individual EngD alumni and industry partners. By integrating the two perspectives, this study provides multiple dimensions to the understanding of the impact from the scheme (see **Annex 2**).

Whilst the data-sets collected in the interviews were relatively small, efforts were made to include the diversity of the contexts to be represented in the study – industry sectors and different types of IDCs across the UK.

- For the RE alumni, efforts were made to cover alumni from different IDCs/EngD Centres, including different industrial experiences prior to the EngD, variety of career paths after the EngD, covering sectoral diversity of the industry they work with, as well as diversity in terms of age and gender.
- For industry contacts, in addition to the contacts made through the IDCs, the research team made direct contacts with individual firms with repeated experiences of EngD programmes (see EPSRC,

2007 Annex; Annex 4 in this report) so that a diverse range of industry sectors would be included in the interviews.

A limited number of interviews were conducted with voluntary respondents, including

- 20 RE alumni (across eight IDCs and one EngD Centre) and
- 15 industry contact persons (across 10 industry sectors and specific organisation types)

Telephone interviews (average duration 30 minutes, recorded and transcribed) were conducted between June and August 2013. Sampling strategies took multiple forms. In consultation with the sub-group, it was decided to ask the IDCs to provide direct introduction to the alumni and key industry contacts. An email request was sent through the AEngD, and initial contacts were given by six of the 2009 IDC cohorts and one EngD Centre. The EngD Impact study was publicised through the AEngD website, Newsletter, and CBI Intercompany Academic Relations Working Group (ICARG) Mailing List through which a few additional interviewees (both alumni and industry) volunteered to participate.

In parallel to the interviews, in order to gain a better understanding of the career paths of REs after the EngD completion, the research team commissioned the Higher Education Statistical Agency (HESA) to identify the EPSRC funded EngD graduates in the Destinations of Leavers of Higher Education (DLHE) survey data (**Annex 3**). The size of the available data is small, but this would provide an overview of the characteristics and destinations of recent cohorts of EngD graduates (2008/09-2010/11 academic years combined). When appropriate, data on the EPSRC funded Industrial CASE graduates, and Other PhD graduates across all the discipline areas are referred to in order to highlight the nature of the EngD impacts. Information about the current sponsoring firms were collated from the existing 20 IDC websites, and a preliminary network visualisation method was employed to show linkages between IDCs and sponsoring firms (**Annex 4**).

The analysis in this pilot study is based on 'snapshots' of impacts by combining different sources – IDC's self-evaluation of their impacts presented in the mid-term review, individual perspectives gained from interviews with both EngD alumni and industry partners, supplemented by other data sets including the HESA DLHE data. There are methodological limitations to the study, which need to be borne in mind when using the information presented in this report. Key limitations of the research design and methodology are summarised below, drawing insights from a recent study (e.g. DTZ/EPSRC, 2011).

- The interview results are limited in terms of the *industry sector representativeness.* Whilst the study aimed to illustrate individual views and experiences covering diverse sectors, the number of contacts in each industry sector is limited,
- *Selection of interviewees and sampling biases.* The selection process of the interviewees resulted in certain biases. The research team had to rely on the voluntary participation of EngD alumni and industry partners. In some cases, the contacts were provided by the centres. It is likely that the centres gave contacts of those individuals who would provide positive views on the EngD.
- *Views on the impact of the EngD*. Both EngD alumni and industry partners as well as IDCs may have a vested interest in the EngD model. The perceptions of the impacts gained in the interviews and mid-term reviews may be rather subjective. Where possible, the research team attempted to triangulate the interviewee's perceptions.
- The samples of the EngD graduates available in the HESA DLHE data are limited in number and it is difficult to compare with other doctoral schemes.

As mentioned already, where there is weak or limited evidence, this is highlighted in the text, and recommendations are made for a future study.

4. Historical background and existing evidence of the EngD impacts

The EngD scheme has evolved over the past 20 years. The earliest EngD Centres started in 1992 with pilots at Universities of Warwick, Manchester/UMIST and Swansea, joined by Brunel, Surrey and Cranfield in 1993. In 1997, the EngD scheme was expanded and centre themes were introduced. There were further cohorts of EngD Centres created under the subsequent calls for funding from the EPSRC in 2001 and 2003. Since 2004, the EPSRC changed the doctoral training funding mechanisms; block grants were given to Centres via the Collaborative Training Account (CTA) funded by host universities instead of individual studentships (see EPSRC, 2007).

As mentioned in Section 1, the EPSRC review in 2007 evaluated the impact of the EngD programmes positively. The EngD programmes were meeting real business needs, and many of the REs were having "a major impact on business performance", and the scheme was making a valuable contribution to UK knowledge generation and transfer into industry, while satisfying its goals in terms of scholarship and publication (EPSRC, 2007). The review also pointed out:

- *…data was not available in any systematic way on the longer term economic impact on the businesses involved.*
- *The destination of REs after completion was perceived to vary greatly between Centres. The great majority of REs have thus far found jobs in industry, often with their sponsoring company.*
- *Most of the longer established Centres do have mechanisms to engage Alumni (both the REs and past sponsors), which should provide a suitable channel for assessing impact over time, using the methodology from the proposed EPSRC impact study.*
- *The Centres should be encouraged to identify the impact of REs on the sponsoring organisations' direct and indirect value chains in order to determine the long-term value of the EngD Programme and use such data and case studies of success to promote and market the scheme.*

One of the key issues raised in the review is the "branding" of the EngD scheme – "what constitutes an EngD and how it differs from a PhD?" The same question was asked in this study and views from the industry partners and RE alumni, in relation to the perceptions of the impact of the scheme, are provided in **Annex 2**.

More granulated forms of evidence of the impact of the EngD are found in the "Review of the Engineering Doctorate Scheme: Stakeholders Survey" prepared by Strategic Marketing Associates for the EPSRC in April 2006. The study provides an assessment of the impact and appropriateness of the EngD scheme from those involved in the scheme. The methodology included 540 self-complete questionnaires, covering both current and past REs, academics and industry supervisors, as well as in-depth interviews.

A study conducted by PA Consulting/SQW Consulting (2007) on the impact of the Research Councils shows the effects of the "development of human capital as a major impact channel from investment in research." The study shows economic impacts of the EngD scheme as follows:

> *EngD graduates, relative to other PhD graduates in similar disciplines, enjoyed significantly higher salaries (between £100,000 and £300,000 over their careers) as a result of their training. The aggregate salary benefit resulting from EngD over the case study period, therefore, could be as much as £80 million, if all achieve the highest salary benefit, for an EPSRC investment of around £12 million*. (p.43)

The above mentioned PA Consulting Group/ SQW Consulting report (2007) uses the salary benefits for cohort estimated as £80 million (maximum), as a proxy for economic impact. This estimate is based on the case study of the earlier EngD Centres (1992/3-1996-7). The scenarios and estimates provide useful methodological frameworks and indicative economic impacts from the EngD programmes in the early period of the scheme (see PA Consulting and SQW Consulting, 2007 b, 2007c). However, the economic impact analysis in general requires a careful interpretation as these estimates contain a "chain of escalating uncertainty" (Martin and Tang, 2007) based on a series of assumptions.

The same report also identified a number of forms of "contribution to innovations from EngD students", including:

- *a new test method estimated to have saved £ millions by reducing warranty returns;*
- *a premium product with lower manufacturing overheads, realising a total margin of £ tens of millions annually;*
- *a new lower environmental impact product that has become the world leader; novel engine management techniques yielding significant fuel and cost savings, and*
- *lower volumes of persistent pollutants with implications for climate change*

These constitute "innovation-related routes to impacts" (see **Figure 2**, Section 2)

In 2009, 19 Industrial Doctorate Centres (IDCs) were created as a subset of EPSRC's new Centres for Doctoral Training (CDTs). The IDCs provide the EngD programmes as an educational, training and research activity, and the universities award the EngD degree rather than PhD. The IDCs are seen as a development of EPSRC's EngD Centres (EPSRC, 2011). The aim of the IDC scheme is 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, 2011). The EPSRC "IDC Scheme Good Practice Guideline" states (EPSRC, 2011, pp.3-4):

> *The Engineering Doctorate (EngD) should be at least equivalent to the intellectual challenge of a PhD, but enhanced by the provision of taught material in both management and technical areas. The training provided should be flexible and should evolve in line with the emerging needs of the individual and the sponsoring companies/sectors.*
>
> *The Research Engineers are expected to spend around 75% of their time working directly with the collaborating company on project work and 25% on taught courses.*

In May 2011, a mid-term review was held with 45 CDTs including 19 IDCs funded in 2009, along with a number of longer standing centres. The review required the Centres to demonstrate progress and impact in their areas. The panel observed that (EPSRC, 2012a):

> *IDCs do deliver a unique student experience and effective, high-quality collaborative research.*

As already mentioned, the number of students trained at IDCs under the EngD programme amounts to about 1,400 and the number of company partners under the EngD scheme amounts to 600 over time (Golby, 2012). It is worthwhile pointing out that the overall doctoral training scheme has built on many of the features of the EngD Scheme (EPSRC, 2007).

> *EPSRC Centres for Doctoral Training evolved over time, from the EngD centres established in 1992, through the Life Science Initiative centres in 2002, to a large roll out of the concept in 2009* (EPSRC, 2012b).

The recent review of business university collaboration (Wilson, 2012) commends that the EngD is not only a mechanisms for knowledge exchange but also for skills development by engaging employers in collaborative research.

In the autumn of 2012, the new call for funding for Centres for Doctoral Training (CDTs) was issued, and there was a strong expectation about the 'user engagement' in doctoral training, The IDC has now been integrated as part of the CDT call (EPSRC 2013a):

> *Formal Industrial Doctorate Centres (IDCs) would be welcome where appropriate and some priority descriptions indicate that a formal IDC arrangement is desirable or compulsory. These user-oriented Centres provide the same training environment and features as CDTs whilst also incorporating a stronger industrial focus. We expect such centres that emerge to be a true reflection of a joint collaborative vision.*

The CDT call selection process took place throughout 2013.

For the historical evolution of the EngD programme and recent IDCs, see EPSRC (2007) and Godfrey (2012). **Table 2** below presents key timeline of the evolution of the EngD scheme since 1990 until 2013.

Table 2: The EngD key timeline and evolution

(Source: EPSRC, 2007, EPSRC 2011; EPSRC, 2012 b)

1990	Parnaby Report
1992	EngD Scheme started
1997	EngD Scheme expanded
2005	Funding mechanisms changed (CTAs)
2007	EPSRC EngD Review Report
2009	19 IDCs funded
2011	CDT mid-term review
2013	Call for CDTs

5. Key findings and lessons learned

In this section, key findings from the data collected and analysed as part of this pilot study are presented under the following three themes: 1) review of the 18 IDCs mid-term review reports, 2) interviews with EngD alumni and industry, and 3) the HESA DLHE (Destinations of the Leavers of Higher Education) survey data analysis. The data-sets collected are presented in **Annex 1, 2 and 3**.

5.1 Review of the 18 IDCs mid-term review reports

The IDC mid-term review that each of the IDCs submitted to the EPSRC in May 2011 provides a set of information on the various dimensions of outputs, outcomes and impact from the IDCs set up in 2009. The study initially identified the key contextual factors that influence the forms and extent of the EngD impacts, including the nature of the IDCs, characteristics and strategies of the sponsoring firms, nature of the EngD projects and the demography and strategies of the REs.

A number of forms of and routes to the impacts are identified in the mid-term review. These are presented in Table 3 in relation to the four areas of routes to the impact identified in Section 2:

Table 3: Forms of and routes to the impact in the mid-term review (Source: IDC mid-term review, May 2011)

<table>
<tr><th colspan="2">Routes to impact</th><th>Forms of impact</th></tr>
<tr><td rowspan="2"><u>Generation of new knowledge</u></td><td>Academic outputs/outcomes</td><td rowspan="15">Economic benefits and financial impacts
- Direct economic impact from the EngD projects
-Additional funding generated through EngD
- “Value for money”

Broader impacts
- Indirect impacts
- RE career paths
- Organisational changes
- Business development
- Policy change, development of codes of practices,
- Influences in the sector
- Career paths</td></tr>
<tr><td>Increased in-house knowledge and research outcomes (e.g. new knowledge, methods and processes)</td></tr>
<tr><td rowspan="3"><u>Innovation related outputs and outcomes</u></td><td>Time to market and innovative change processes</td></tr>
<tr><td>Commercialisation (e.g. new products, services)</td></tr>
<tr><td>Spin-out companies</td></tr>
<tr><td rowspan="4"><u>Knowledge networks and collaboration</u></td><td>Strategic research collaboration</td></tr>
<tr><td>IDCs as the hub for collaboration</td></tr>
<tr><td>Sector-based approaches</td></tr>
<tr><td>Internationalisation of collaborative relationships</td></tr>
<tr><td rowspan="5"><u>Human capital and skills development, mobility and knowledge exchange</u></td><td>REs as agents of change</td></tr>
<tr><td>Individual and organisational capability development</td></tr>
<tr><td>Enhanced opportunities for Continuing Professional Development (CPD)</td></tr>
<tr><td>Industry Fellowships/Innovation Awards</td></tr>
<tr><td>Enhanced people mobility and knowledge exchange</td></tr>
</table>

Key findings identified in the mid-term review are as follows:

- Each IDC uses their own definitions and frameworks to capture and present a variety of forms of impacts in the mid-term review, ranging from direct financial benefits to wider social change (see **Table 3** above).
- Forms of industry impact identified in the mid-term review include: *new products, tools, services, and development of new systems* and *business processes*. In addition, longer term impacts are presented including: *societal changes*, *policy influences*, as well as *behavioural changes of businesses and organisations*.
- There are a number of less tangible and indirect forms of impact from the EngD that are identified in mid-term review reports such as "agile response to research opportunities" leading to a new industry collaboration, "developing capabilities", changes in business practices and processes such as "efficiency in the production pipeline", "making better decisions in medical planning", and acceleration in innovation by reducing time to market.

Following the above mentioned EngD/IDC routes to impact framework (**Figure 2**), some of the quantifiable "key metrics" of the EngD scheme are presented below.

Table 4: Exemplars of the EngD/IDC "Key Metrics" (Source: EPSRC 18 IDC mid-term review)

	EngD/IDC inputs(2009-2013)			**Outputs/Outcomes (Routes to impact)**	**Impact** Quantifiable examples in the mid-term review
	EPSRC funding	*Leverage* (Section 5.2)	*Resources*		
Per IDC	£ 4.5 M on average	Industry cash; £2.5M on average; Estimated in-kind contribution £2M; University cash and in-kind contribution	Industry supervisor time Facilities, equipment; Access to company's training; Academic supervisor time Facilities, equipment; Teaching and training	• Generation of new knowledge • Innovation related outputs and outcomes • Knowledge networks and collaboration • Human capital and skills development, mobility and knowledge exchange	"Saving of industry sponsor" "The total additional average declared contribution per RE" "added value" of the EngD in financial terms

Inputs - For the 2009 IDCs, the EPSRC invested £4.5 million per IDC on average ("*The average cost to EPSRC per RE is £90K"* according to the CDT mid-term review*).* This investment leveraged direct additional funding from industry partners. According to one IDC, cash contribution from industry partners is reported to be "£2.5 million per IDC" on average. Another IDC states in the mid-term review "All sponsors pay at least £12K per annum to the IDC: £8K to IDC running costs and £4K to the RE". However, in-kind contribution is difficult to estimate and difficult to present due to confidentiality. According to the figures provided by one of the IDCs in the mid-term review, it is estimated at around £2 million per IDC, based on "*£40K per RE per year".*

Impacts – A number of EngD impact examples related to direct financial benefits are identified in mid-term reviews, as well as in the testimonial documents from industrial sponsors. However, these data sets are not collected and presented in a consistent manner across the IDCs. A few IDCs provided their economic impact estimation of the EngD programmes in the mid-term review reports but the frameworks of their impact estimation seem to differ substantially between the IDCs.

- **Direct financial benefits from the EngD projects**

There are numerous examples identified in the mid-term review reports. See **Annex 2** for more details. For example, according to one of the IDCs, one EngD project is reported to *have saved the sponsoring firm £0.9 million in 2009 and £2.4 million in 2010* [SEES IDC]. Another IDC notes in mid-term review: *estimated labour savings of 80% in a market sector worth $1.5 billion* [Bioprocess Engineering Leadership IDC]; and *The resultant throughout saves us £1 million per annum* [Formulation Engineering IDC, testimonial letter].

- **Economic impacts of the IDC**

There is no standard set of methodology employed and data available in the mid-term review reports for evaluating the overall economic impact of the EngD. Information related to various forms of impacts is provided in different parts of the mid-term review report (see **Table 8, Annex**). As an example, Section 1.2 of the mid-term review asks "How has the IDC demonstrated added value (e.g. value for money, comparisons with a standard doctorate), and in what ways has the IDC programme benefitted from its larger scale". **Box 1** shows one IDC that presents the "added value" of the EngD in financial terms as follows:

Box 1 The "added value" of the EngD in financial terms (Source: IDC mid-term review, Section 1.2)

-The average cost to EPSRC per RE is £90K
-The average cash contribution per RE from industry is £61K
-The average cash contribution per RE from the university is £6K
-The average declared value for typical project is £92K
-The total additional average declared contribution per RE is £159K

The IDC states that "accurate and rigorous real in-kind contribution is problematic due to confidentiality issues and variable accounting processes". Based on the figures provided by this IDC in the mid-term review, the added value of the EngD equates to a leverage of an additional £1.77 for every £1 invested by the EPSRC (our own calculation).

Issues and recommendations

- An examination of the mid-term review reports provided by the 18 IDCs suggests that more coherent approaches to data collection and presentation are required to better evidence the impact of the EngD projects and programmes. For future reviews of impact it would be helpful to have clearer definitions of some terms (e.g. value for money).
- A clear typology of impacts and methodological frameworks are needed, that aide estimates of economic impacts (e.g. direct impacts on GVA, indirect and induced effects), as well as wider impacts and benefits from the EngD (for economic impact analyses, see Deloitte, 2012; DTZ/EPSRC, 2011; Scottish Enterprise 2008;PA Consulting Group/SQW Consulting, 2007; 2007b; 2007c).
- It would be helpful for future reviews of impact if there was clearer methodological guidance for the mid-term review process in order to distinguish different routes to impacts (i.e. outputs and outcomes), and to evaluate and estimate economic impacts of the EngD projects and programme in a more systematic way.

- Similarly, to better understand and capture the impacts of the EngD to industry sponsors, a clearer methodology and guidance is needed for the industry sponsors, in order to identify impacts from the EngD projects and programme in their businesses, both short term and long term.

Details of the EngD impact identified in the mid-term review are presented in **Annex 1** along with the following data and information:

Table 7 – the list of the 18 IDCs.

Table 8 – Mid-term review sections and questions related to the EngD impact

Table 9 – Forms of and routes to the impact – examples from the IDCs mid-term review

Evidence of these impacts was further collected through the interviews (see **5-2** below and **Annex 2**).

5.2 Interviews with Industry partners and EngD alumni

Interview findings provided evidence to the conditions, forms and routes to the impacts which supplement the findings from the examination of the mid-term review. As already mentioned in Section 3, interview samples are limited in nature. However, for this pilot study, the small scale qualitative set of data provided some advantages. It gives contextual understanding of the diversity of the IDCs, individual experiences and perceptions of the EngD projects and various forms of impact over time, which were not captured in the mid-term review analysis. Interview findings presented in the Annex provide illustrative samples of the diversity of the contexts leading to the impact. Further evidence is required in order to ensure the representativeness of the interview results and make the findings more generalisable. Interview results in particular illuminated perceptions of both EngD alumni and industry sponsors about the variety of forms of impacts of the EngD programmes, routes and barriers to the impact, at individual, organisational and sector levels. Consideration was given in understanding and explaining the differences in impact, highlighting factors such as career paths, the nature of the technology, the nature of the company and sectoral differences.

A number of common types of impact, experiences and themes emerged during the analysis, and differences between individuals, organisations and sectors were also demonstrated. The four types of routes to impact identified earlier are used to collect evidence of the EngD impact from the interviews.

- **Generation of new knowledge** leads to increased in-house knowledge and research outcomes in the short-term, and a long-term approach to technology problem solution and business change. Standard formation and policy change based on knowledge generated from the EngD projects are long-term routes to impact, leading to sector-wide and/or broad social change.
- **Innovation-related routes to impact** include *new product/service development*, *new market entry*, *improvements to business processes* and *cost savings*. Licensing of patents and the formation of spin-out companies are other impact routes to commercialise the EngD projects.
- **Human capital and skills development** routes include: 1) individual RE career path developments; 2) organisational absorptive capacity development at the industry partner; and 3) the sectoral-wide impact by creating a pool of skilled talents.
- **Through knowledge networks and collaborative relationships**, EngD projects provide benefits at an industry-wide level which could not be captured by one company alone. Knowledge generated by one firm often diffuses into the industry as a whole through collaborative relationships, through supply chains or through movement of human capital. The IDCs and the EngD Centres act as a hub for such wider impact routes.

There are both *tangible and short-term outputs and mid/long-term outcomes* from the EngD programme, as well as *intangible and long-term outcomes* leading to even bigger impacts which may not be quantifiable.

Table 5 below summarises the typology of the impact and possible forms of evidence as gathered from the interviews.

Table 5: Types of the EngD impact based on the interviews

Routes to Impact	Short term (i.e. during the programme)		Mid/Long term	
	Output/Outcome	Evidence based examples	Output/Outcome	Evidence based examples
Generation of new knowledge	**Increased in-house knowledge and research outcomes**	*Published papers* *Conference papers*	**Long-term approach to technology problem solution and business change** **Policy change**	*Change in regulation, Codes of practices*
Innovation	**New technology, new instruments, new measures, processing**	*Patents* *Cost-savings* *Accelerated time to market*	**New business processes** **Future strategic changes** **New products, new services** **Creation of new business** **Sector-wide problem solving**	*Business development* *Leveraged Investment* *Revenue generation* *Spin-out companies*
Knowledge networks and collaboration	**Sector-wide problem identification** **Networks created by IDCs**	*Co-funding of EngD projects* *Event participation*	**Technology supply chain** **Further collaboration with academic and/or with other firms**	*Sharing of facilities, Collaboration across the sector/ Academia*
Human capital and skills development	**RE's academic and technological advancement** **Skills Development and Organisational Learning** **New employment**	*REs' research progress* *Training* *Employees' CPD opportunities* *Recruitment of the RE*	**EngD alumni promotion and progression** **Future management and leadership roles** **Pool of skills and human capital in the sector; Inter-sectoral labour mobility**	*Chartered Engineer status* *Salary benefits* *EngD alumni networks*

Key messages from the two groups of stakeholders - industry partners and EngD alumni - are presented below. The details of interview results and quotes from the interviews with the industry partners and EngD alumni are presented in **Annex 2**.

5.2.1 Industry partners – interview findings

The nature and the aim of each EngD project differs according to the motivations and objectives of the sponsoring firms, which would shape their perception and evaluation of the 'impact' of the EngD and expected time scales.

- The EngD programme is seen as a unique scheme and supported by the industry partners because of:
  1. The "portfolio of the projects" compared to the specialised nature of the PhD;
  2. The time REs spend within the industry, which is much longer than the PhD and
  3. The direct contacts and control industry partners have over the nature of the project.
- From an industry perspective it is important to have a "balanced portfolio of R&D activities and skills." It is argued that different centre types – CDTs and IDCs - complement the R&D activities across the industry sectors covering different scopes of technology and different types of skills needed for the future leadership and technical research in industry.
- *"Distinctive advantage of EngD is the fact that it is applied in nature. The EngD allows much closer interactions, closer support system than the PhD. However, this is one model – the spectrum of*

models – both PhD and EngD are needed."

- Indicators for industry in order to measure the EngD impact may include: number of products and patents related to EngD projects, and the number and quality of EngD graduates recruited into industry. Publications and participation at conferences are seen as outcomes that raise the profile of the company.

Human capital development

- Sponsoring firms often act as a potential employer as well as a research sponsor. Several of the industry partners interviewed use the EngD programme as a tool for employing key talents, where the impact of the EngD programme is seen as mid to long-term [e.g. manufacturing, pharmaceutical, water management].
- Some of the industry sponsors emphasise the importance of the EngD/IDC scheme as a "deliberate mechanism by the sector" in developing the next generation of scientists and engineers [e.g. water management, nuclear engineering].
- Some firms have integrated REs as part of their human resource management through reward and recognition mechanisms [e.g. energy, water management].

Various forms of impacts

- Some sponsoring firms use the EngD project to solve a specific and immediate business problem they are facing [e.g. retail] and/or to gain state-of-the-art research expertise [e.g. consumer goods, energy]. *"We use the EngD project as a buffer, using external doctoral students to respond to specific research needs"*
- One industry partner [Retail] clearly separates the EngD from their recruiting processes. They see the EngD projects as "direct solutions to the industry problems". They have highly appreciated the impact from the projects and immediately rolled out the impacts. However, they don't see the REs as future employees as the areas of the EngD projects are specific and not the core part of their business.

Box 2 Industry problem solving, new modelling tools and financial impacts

A large UK-based retail company has recently hosted two EngD projects to look for "new technologies, developing/testing a new method of innovation." Within two years, one of the projects resulted in the development of "modelling tools for calculating energy consumption of buildings." The new modelling tools have been implemented in the company's UK stores, as well as its overseas stores, resulting in "substantial cost savings of nearly £5 million."

"*The RE did a project about energy efficiency behaviour about 13-14 months ago; we did a roll out through all the stores across UK, involving 300,000 people. Electricity consumption is quite significant, and we were looking at electricity consumption savings across the UK. Within 18 months of the start of the EngD project we managed to come up with savings worth several million pounds; the RE already helped deliver that as a benefit*."

- *"The EngD can be used to kick-start new technologies."* One industry interviewee *[geoscience]* states that an RE in his firm managed to find a new process in terms of security application which helped the firm to expand into new business territories and markets. Consequently, some part of the technology from the EngD project resulted in a spin-out firm from the sponsoring company.
- Due to the high costs and limitation of resources in an early stage of technology developments, it is often difficult for companies to invest and develop new technologies. EngD projects could fill such

gaps. However, one interviewee pointed out the difficulty for a small early start-up company to commit resources to EngD projects.

- Technological development from EngD projects, such as new software and processing, may lead to new products and new markets [e.g. manufacturing]. Using the result of the EngD programmes can lead to new business processes, and furthermore, broader and long-term impact across the sector, including supply chain management, industry-related standards and sector-wide policies [e.g. consumer goods, water management].

Spill-over effects of the EngD

- Some of the sponsoring firms send their employees to the technical and business related courses as part of the EngD programmes as continuing professional development (CPD) [e.g. pharmaceutical, consumer goods]. The EngD projects have also had impact on the organisational capability through improved skills and knowledge, not only the RE but also the industry supervisor and other employees.
- Some of the IDCs take a strong sector-based approach. Sponsoring companies sometimes work together to solve the sector-wide problems by identifying common issues and co-sponsoring EngD projects.
- Some IDCs have developed networks and relationships between firms, acting as the "core part of the R&D supply chains", by providing technical expertise, sharing equipment and providing training courses.

Box 3 Sector-wide synergy and impacts

The impact of the EngD is recognised as sector-wide, beyond individual projects and technologies. For example, through the IDC in Nuclear Engineering, two companies started to work together leading to a new collaborative funding of the EngD project. One company provides an industry problem and another company funds the project where their commercial tool gets validated. The RE will spend 50% of their time at each of the companies. This is seen as "*a real synergy and an added value of the IDC"* [a sponsoring company].

"There is a long time gain for the sector through the sponsoring firm, not just individual EngD and technical impact…..Through the IDC management board meetings, a number of industries come together and when common areas emerge we can do a joint funding….."

Issues and recommendations

- It is generally difficult to capture the long term impacts and financial impact of the EngD project. For instance, it may take several years before the technology gets commercialised.
- Especially when the RE has left the sponsoring company after the completion of the EngD, it is difficult to track the impacts of the EngD project within the firm, apart from the immediate and short term outcomes.
- The IDCs may develop more strategic and systematic monitoring approaches in collaboration with sponsoring companies about various forms of EngD impacts, both short term and long term. This may include technological impact, financial impacts, skills development of the REs and other employees, employment of the REs, sector-wide changes arising from the EngD, and long term social impact of the EngD project (e.g. supply chain relationships; see CBI, 2014).
- Industry sees the EngD scheme as "value for money." Some interviewees mentioned that EngD provides more value in comparison to other collaborative research mechanisms such as hiring

post-doctoral researchers and other collaborative PhDs (e.g. the CASE PhD studentship). However there is a lack of solid evidence to understand the impact of different collaborative mechanisms.

- There is a shortage of thorough data on a range of benefits from the EngD on industry partners. More contextualised evidence and relevant sets of indicators are required to understand the impact as perceived by industry partners. For instance, further data collection is required including: *objectives* of industry to participate in a particular type of collaboration, *forms of the evaluation* of the impacts conducted by industry partners, both short term and long term, and the *trajectories* of how the industry sponsors have rolled out the impacts from the collaboration.

5.2.2 EngD alumni career paths – interview findings

Career paths and progression of the EngD graduates indicate the impact of the EngD. Typology of the EngD alumni and their career trajectories was made based on the interview findings. In terms of prior experiences,

1) Those without (or less than one year) industry working experience (*fresh graduates*),
2) Those who had had working experiences in industry prior to the enrolment of the EngD (*RE experienced*).

In terms of destinations after the completion of the EngD,

3) Those who stayed on at their sponsoring companies as an employee, and
4) The REs who left the sponsoring companies at the end of the EngD and found jobs in the same industry or in a different sector.

According to the interviews, the **"**opportunity to work within the industry, whilst conducting academic research", was identified as the main motivation for the former REs joining the EngD programme. The commercial aspects and industry-based nature of the scheme are also recognised as main motivations. Majority of the RE work in industry after the EngD programme whilst a few EngD alumni have worked across industry and academia after the completion of the EngD.

Qualifications and skills

- The EngD qualification with a business/management related qualification seems to advantage their professional status within the labour market, especially when they work in industry. In particular, the business qualifications and training have helped broadening REs' career choices; for example, expanding from purely technical backgrounds to more managerial roles:
  "It was the management courses (in the EngD programme) that encouraged me to pursue a management career in the company, rather than a technical one" (EngD alumnus)

- Interviews with the EngD alumni highlighted issues for experienced REs, in particular. Many of them expressed concerns they had over returning to education in the midst of their career. The EngD, they believe, is the right channel to help them maintain their positions within the industry as there will be arguably no hiatus in their career ladder, compared to taking on a purely academic doctoral, such as the traditional PhD. See **Box 4**.
- In addition to tangible qualifications, former REs have benefited from broad range of skills and competences gained through the EngD programme including technical, analytical, transferable and business related skills, as well as working experiences during the programme embedded within industry. One former EngD student commented on her career development after the EngD programme (Manufacturing) moving into a banking sector.

"Personally the EngD gave me confidence to look into different industry – far reaching different job opportunities." ….tangible skills, project management experiences, maturity, overall exposure to business environment, finance management, operational management, working with different people, working on commercial goals; all useful to advance my career."

- The EngD programme helps former REs obtain further professional qualifications. Those EngD alumni who already obtained the Chartered Engineer status believe the process had been aided and accelerated by the EngD qualification.

Forms of impact

- There are a number of tangible outputs, outcomes and benefits from the EngD programme identified by the former REs including *patent applications*, *formation of a spin-out company* (see **Box 5**), *employment* either at the sponsoring firm or in other firm/sector, and a relatively rapid promotion/progression.

- The indirect impacts of the EngD on the career paths include broader commercial and entrepreneurial opportunities created by the former REs themselves. For example, a former RE [CICE IDC] received additional investment to create a new venture related to his EngD project outcomes within the sponsoring company, which subsequently led to significant financial benefits. The EngD experience may have helped such skills and ability to spot and create opportunities. These indirect impacts are not well captured in the mid-term review.

Box 4 Case study – an experienced RE career development

A former RE *(EngD in Manufacturing,* graduated in 2009) was already an experienced engineer when he entered the EngD programme. Following the closure of his previous employer, he applied for an EngD position seeing it as an opportunity for long-term career development. His EngD project was sponsored and based in the UK based large electricity and gas company.

"I like that the EngD programme requires REs to spend time in the company. You'll benefit from having a position in industry rather than doing pure academic research. This is important for people who are already in the industry (because) it's hard for them to go back to academia.....The well-constructed management program opened my mind to different parts of life. My career prospects have been transformed immensely by the Engineering Doctorate, due to the combined technical and professional development elements forming it. The good thing about that is I'm now able to use the skills in real life. ... the combination of this expertise and the tools learnt will definitely help to advance my career prospects even further.

Following his EngD, the RE was offered a job and continued working for his sponsoring company as a senior engineer, and took up management responsibilities. After four years he left the company and moved overseas to take on a specialist engineering role with one of the largest international oil suppliers in the world. Currently he is leading a strategic project to enhance the reliability of the subsea cable network feeding critical offshore oil producing facilities. He suggested that the EngD programme would be of interest to international companies like his and a great opportunity to develop talent pools in a global context.

Box 5 Case study Entrepreneurial impacts from EngD project

RE (Optics & Photonics, IDC) has over 10 years experience in electronics engineering and international R&D policy work. He started the EngD programme with an interest in 3D display technology and creating a high-tech start-up company. The RE founded the firm in 2008 and by appointing a technology entrepreneur on the board of the company, who acted as the industrial supervisor, the start-up company has been able to 'host' the EngD project. During his EngD, one patent was granted, some £300,000 raised and the company now has four employees. The holographic display technology has been featured on The Gadget Show TV programme and the innovation from the EngD research has been disseminated through various media, including a trade magazine, conferences and newspapers. He has also won numerous prizes, awards and grants to support his research. With regards to his skills development, the RE comments:

"the MBA component was excellent for starting up a company, especially the marketing, accounting and finance modules as I had to write business plans and pitch for funding to raise money from private investors."

Although having an EngD project based in the RE's own start-up company is a rare case across the EngD centres/IDCs, the RE argues that the EngD programmes should be more "entrepreneurial and risk taking" in their approach. He recommends that the EngD programme should "*target more small and medium high-tech companies as they would add more value, given that SMEs create more jobs and can innovate faster*." Furthermore, he suggests that more mature people with industry experiences who want to make career change could use EngD by trying out new ideas, and there should be more supports for this.

Issues and recommendations

- Career development and pathways of the former REs are diverse where different forms of EngD impacts are embedded. Detailed case studies of EngD alumni and their career pathways in different discipline areas, industry sectors, and different types and sizes of sponsoring firms would add value in order to enrich our understanding of EngD impacts.
- An EngD qualification is likely to contribute to the demonstration of the required standard of competence and commitment for the award of Chartered Engineer (CEng) status. An EngD that is accredited by the engineering profession will make the assessment process for the award of CEng status more straightforward. However, there is very limited information collected about the career development of EngD alumni.
- Quantitative data on destinations and career development of the EngD graduates and information about further professional qualifications such as Chartered Engineer status need to be systematically collected and analysed.
- More comparative data sets would help understand career progression of EngD alumni. For example information could be sought on salary benefits between EngD alumni and "a cohort of otherwise identical individuals" (e.g. those who hold PhDs instead of EngD post graduate qualifications; those who had worked in industry over 4 years after undergraduate qualifications or Masters qualifications) (see PA Consulting Group/SQW Consulting, 2007c, for methodologies of the economic impact analysis).
- The former REs would be a vital agent who can communicate the value and impacts of the EngD, and closer alignment could be made between the EngD Centres, IDCs and the AEngD for alumni relationship building.

5.3 The EngD career paths - HESA Destinations of the Leavers of Higher Education Survey

The interview findings demonstrate that career development and pathways of the EngD alumni are diverse and need more data sets and comparative analysis. Destinations and the career pathways of the EngD alumni need to be more systematically collected across the IDCs.

In addition to the main qualitative evidence of the EngD career paths provided in the interviews, quantitative data was collated for this pilot study from the HESA Destinations of Leavers of Higher Education (DLHE) Survey data. The DLHE data are collected from the graduates from the UK higher education institutions (HEIs) six months after the graduation of their programmes.

Comparing data of the EngD graduates with other types of doctoral graduates (e.g. Industrial CASE, PhDs at CDTs and other PhDs) would be of value in understanding the nature of different types of doctoral research training and their impacts. However, each doctoral scheme has been established with distinctive objectives, which have changed over the years. This makes data availability and comparative analysis difficult and sometimes problematic.

The data on EngD graduates was initially obtained from the EPSRC, which was matched and integrated into the DLHE data by the HESA. Data on recent cohorts of students (2008/09-2010/11 academic years combined) was made available for analysis, in which the data of 125 EngD graduates and the equivalent data of 201 Industrial CASE graduates were identified over the three year cohorts. Where appropriate, the HESA DLHE data on "Other PhD" leavers across all disciplines (total number 20,795; 2008/09-2010/11 academic years combined) is stated. The main purpose of the analysis is not to compare these different types of doctoral programmes, but to illustrate various contexts of impacts related to the industrially co-

sponsored doctoral schemes (see PA Consulting Group/SQW Consulting (2007b). Some of the key findings are presented below. See **Annex 3** for more details of each of the doctoral schemes, the data and analysis.

- Majority of the EngD graduates work in industry than in academia.
- Six months after the completion of the programmes, 91.2% of EngD graduates are in Full-time paid work (including self-employed). This compares favourably to Industrial CASE graduates (79.6%) and Other PhD (73.9%).
- Salary data available in the DLHE survey data sample is small and generalisation is difficult. The data shows that for those who are in employment, 33.3% of the EngD graduates earn more than £35K per year (**Figures 3**). This figure compares favourably to Industrial CASE and Other PhD graduates.
- In terms of how the graduates found their employment, 24% of the EngD graduates found a job as they "already worked" there (i.e. the sponsoring firm), higher than Industrial CASE graduates (10%) and Other PhD (16%). (**Table 16**). This shows that about one in four REs may be offered a job at the sponsoring firm after the completion of the programme.
- 85% of the EngD graduates work in non-academic sector, with 15% working in Education whilst 66% of Industrial CASE graduates work in non-academic sector with 34% in Education sector. 32% of EngD graduates work in Manufacturing, 27% in Professional, scientific and technical activities (**Table 17**).

Issues and recommendations

- HESA DLHE survey data provides systematic information on the career destinations of the UK HE leavers six months after the completion of their studies. The data on EngD graduates was matched for the purpose of this pilot study. The size of the samples that can be matched from the recent EPSRC record of EngD students is rather small, but provides characteristics of the EngD graduates and their career impacts for this pilot study. However, the sample size of the DLHE data on EngD leavers' salary available for this pilot study is very limited.
- Longitudinal and systematic data analysis is needed in order to understand the impacts of the EngD in terms of career development and progression of the alumni. For example, data in terms of the salary benefits comparing those graduates from industrially targeted PhD studies (e.g. Industrial CASE) and other PhDs in similar subject areas would help illustrate the economic impact of these programmes, whilst careful considerations of the nature of different schemes are required when comparing the data.
- The economic impact study by PA Consulting Group/SQW Consulting (2007; 2007b; 2007c) showed the employment categories and salary benefits of the EngD graduates, relative to other PhD graduates in similar disciplines based on the case study (1992/3-1996/7) (see Section 4). Similar methodologies could be developed and adopted to estimate impacts of the EngD graduates from recent IDCs.

5.4 Summary of findings

The impact is found at the *individual level (i.e. REs and EngD alumni)*, *organisational level (i.e. sponsoring companies, universities and IDCs)* and at the *sector level (i.e. industry, higher education)*. A number of forms of and routes to the impact from the EngD programme were identified in the interviews, which were analysed based on the framework developed from the analysis of mid-term review and review of literature. Broadly, four types of routes to impact are identified:

- *Generation of new knowledge*
- *Innovation*
- *Knowledge networks and collaboration*

- *Human capital and skills development*.

Table 6 below presents key exemplars of the EngD impact found in the mid-term review, interviews and the DLHE survey. See **Annex** for the specific contexts of these exemplars of impact.

Table 6: Key Exemplars of the EngD impact found in the study

Routes to impact	Source	Exemplars of impact
Generation of new knowledge	Industry sponsor interview	• *"The delivery of necessary new scientific insights, or evaluations or development of evaluations of tools, methods and approaches; publications and getting the information out there"* (Consumer Goods).
Innovation related outputs and outcomes	Industry sponsor	• *"The EngD can be used to kick-start new technologies."* (Start-up company related to EngD technology)
	Alumni interview	• "*technology developed through the EngD project was patented and led to the new manufacturing standard within the firm"* (Manufacturing)
Knowledge networks and collaboration	Industry sponsor interview	• *"a long time gain for the sector through the sponsoring firm, not just individual EngD and technical impact"* (Energy) • *"Social and economic impact of the EngD is a very important component of the technology supply chain."* (Manufacturing)
Human capital and skills development	Industry sponsor interview	• *"Employment - most important outcome of the EngD".* (Public research organisation)**; "***potential employees, and also managers, future leaders."* (Manufacturing) • *"An enhanced talent pool."* (Water) • *"Industrial supervisors are part of the learning cycle."* (Energy)
	Alumni interview	• *"the EngD management courses encouraged me to pursue a management career in the company"* (Manufacturing) • *"in 5-6 years I will progress further, compared to someone who has a PhD, which is the advantage of the EngD"* (Nuclear)
	HESA, DLHE 2008/9-20010/11	• 6 months after the completion, 91 % of EngD graduates are in full time paid work, and for those who are in full-time employment, 33% of the EngD graduates earn more than £35K per year. This compares favourably to Industrial CASE and Other PhD graduates.
Economic benefits and impact	IDC mid-term review	• "£33.7 million of additional research council, industry and government funds, including research contracts over 2000-2010" • An EngD project have saved the sponsoring firm £0.9 million in 2009 and £2.4 million in 2010 • One IDC states that "*The total additional average declared contribution per RE is £159K,"* which equates to a leverage of an additional £1.77 for every £1 invested by EPSRC, • One of the earlier EngD project outcomes was a therapy that had an estimated value of $20 billion in 2009
	Industry sponsor interview	• The EngD project outcome "*has been rolled out to Asia; we're forecasting that it will be about £3 million worth of savings this year, on top of UK figures*" (Retail)

Key factors that influence the EngD impact were identified as follows:

- *RE's individual factors* (e.g. age, gender, industry experiences);
- *characteristics of the EngD projects* including the nature of the technology, technological specificity, 'technology readiness level', areas of scientific disciplines;
- *the academic environment and organisational factors*, including the history and characteristics of the IDC/EngD Centre;
- *The nature of the sponsoring firm and the sector*, including firms' hiring decisions, culture and policies towards promotion, as well as organisational strategies of the sponsoring firm.
- *Broader social and institutional conditions,* including the labour market conditions, corporate governance structures and R&D investment in the scientific fields.

The mid-term review analysis, interviews with industry partners and RE alumni and the HESA DLHE analysis led to the following recommendations.

- A careful methodological approach is required for the economic impact analysis. A few IDCs provided their economic impact estimation in the mid-term review reports. However, more coherent methodological guidance and systematic approaches to the data collection are required to better evidence the impact of the IDCs.
- The nature and diversity of industry sponsors – existing and potential ones - has to be better understood, including their motivations, R&D and skills needs and perceived barriers for collaboration.
- In this pilot study, the overview of sponsoring firms suggested that there are more large firms than small and medium-sized enterprises (SMEs) that sponsor the EngD projects. Questions may be asked: What are the conditions for SMEs to work with the collaborative R&D schemes? How do they benefit from working with doctoral students and what are the perceived barriers?
- A strategic monitoring approach and support to the RE by the sponsoring firm would help better capture the outcomes of the EngD during the programme. A broader impact of the EngD programme through *supply chain relationships* needs further investigation.
- Career development and pathways of the former REs are diverse and need more data sets and comparative analysis. Destinations and the career pathways of the former REs need to be more systematically collected across the IDCs. Comparative data of the EngD to other doctorates (e.g. Industry CASE, PhDs at CDTs and other PhDs) is of value in understanding the nature of different types of doctoral research training.
- Evidence is required in terms of the salary benefits and responsibility given to the EngD graduates in employment in comparison to those who went into industry straight after the first degree and worked for four years.
- Both industry and alumni interviewees pointed out that awareness-raising of the EngD scheme is the most important issue. The nature, strengths and mechanisms of the EngD as a collaborative scheme is not well communicated to industry, prospective students and also within academia. Strategic use of general media, such as newspaper, radio or television; disseminating more information about the programme is recommended.

6. Conclusions and future recommendations

This pilot study was commissioned in January 2013 in order to define and understand what the 'impact' of the EngDs is and to identify how it can best be evidenced. Broadly, four routes to the impact from the EngD programme were identified:

- *Generation of new knowledge*
- *Innovation*
- *Knowledge networks and collaboration*
- *Human capital and skills development*.

The evidence collected in this study helps to provide a better understanding of the variety of forms of impact of the EngD, with reference to frameworks that will aid future assessment of economic impact.

There are important areas for future consideration as identified below.

Methodological issues and recommendations

This pilot study aimed to identify and assess various sources of data and enquiry methodologies to understand the impact of the EngD. The methodology adopted in this study has a number of limitations and the findings need further verification. It should be noted that the intangible and interactive nature of the relationship building through the EngD scheme and capturing long term impacts from such relationships provide fundamental methodological challenges to the evaluation of the scheme, especially in terms of a quantifiable measurement.

- In terms of understanding the impact, this report has built on the existing works and identified possible methodological approaches and frameworks to take. Methodological challenges in understanding the EngD impact include the quality of the data and cost of evaluation (see PA Consulting Group and SQW Consulting 2007).
- It is important to understand more granulated contexts of the impact of the EngD *projects* as well as the programme by triangulating the evidence from the key actors at the project level. A broader range of key stakeholders (e.g. academic supervisor, industry supervisor and current EngD student) will have to be consulted by combining different methods such as interviews and surveys (see Strategic Marketing Associate 2006 report for the EPSRC).
- The evaluation methodology and indicators of the impact of the EngD projects and programme, as well as other doctoral programmes, have to be developed in relation to the specific conditions and strategic objectives of each of the programmes – both short-term and long-term.
- Case study methods may be adopted to draw a more comprehensive and detailed picture of economic impact of the EngD programmes by building samples of IDCs and EngD projects, both on an aggregate and on an individual basis (see DTZ/EPSRC, 2011).
- The salary impact model developed by PA Consulting Group and SQW Consulting (2007c) could be further developed and adopted to the cases of more recent EngD programmes at IDCs.
- For the better understanding of the economic impact, the logical next step would be to estimate the Gross Value Add arising from the EngD programmes, taking into account number of jobs created, additionality and attribution factors, to assess the overall "return on investment" (see DTZ/EPSRC, 2011; Scottish Enterprise, 2008). However, such analysis is beyond the scope of this pilot study.
- Other evaluation approaches to research impacts can be combined including co-authorship analysis, biographic coupling and social network analysis (see Youtie et al. 2013).

Evidence base

- Whether or not the EngD programmes brings better outcomes to the industry and to the individual REs than the PhD programmes and other collaborative R&D projects is context dependent and a further study is needed to collect a broad evidence-base (e.g. the nature and objectives of the projects, individual career directions).
- Outputs of the EngD scheme, such as numbers of publications and patents, are used as indicators of the EngD impact, but these are not consistently and systematically captured in the mid-term review across IDCs. A longer-term and more systematic approach to data collection is required. Impacts may be better assessed through detailed surveys of collaborating businesses and other organisations. However, these exercises can be resource-intensive.
- Destinations, career pathways and progression of the former REs need to be more systematically collected across the IDCs in order to better understand the collective benefits of the EngD to individual EngD alumni. The HESA DLHE provides a starting point but limited in terms of the sample size and data comparability.
- Comparative data of the EngD to other doctorates (e.g. Industry CASE, PhDs at CDTs and other PhDs in similar subject areas) would be of value in understanding the nature of different types of doctoral research training.
- Comparative data (e.g. salary) might be useful between the EngD alumni without prior industry experience in employment right after the EngD degree and those who went into industry straight after the first degree and worked for four years.
- A careful methodological approach is required for the economic impact analysis. A coherent methodological guidance and systematic approaches to the data collection on different forms of impacts are required to better evidence the impact of the IDCs (e.g. mid-term review).

Positioning the EngD impact within the R&D and training eco-system

- The impact of the EngD scheme needs to be seen as part of the broader R&D and skills training eco-systems, in light of the organisational R&D and HR strategies, as well as broader R&D supply chain management (see CBI, 2014).
- Different centre types – CDTs and IDCs - complement the R&D activities across the industry sectors covering different scopes of technology and different types of skills needed for the future leadership and technical research in industry.[1] The EngD may align closely with the industry specific R&D and skills needs. Different R&D and skills needs in different industry sectors need further investigation.
- The broader impact of the EngD programme at the sector level, for example, in relation to the UK "Road Map" of future pathways for industry R&D and skills needs, and impacts through supply chain relationships, and a model of "open innovation" need further investigation.

[1] A recent review on *International approaches to manufacturing research* (O'Sullivan, 2011) suggests having EngD studentships within a cohort of PhD students as a way to bring "*potential competitive advantage and enhanced industrial impact to be gained from providing a greater number of manufacturing engineering PhDs with more substantial (and varied) manufacturing industry project experience"*: The report also suggests "*exploring the potential for UK intermediate research institutes (e.g. manufacturing-related Technology Innovation Centres) to facilitate EngD engagement in real-world manufacturing engineering problem-solving*." Whether such a model is applicable to a wider range of IDCs needs further debate.

- Barriers to the EngD impacts need more understanding. For example, during the interviews, the difficulty in attracting good RE candidates, particularly the importance of attracting the experienced engineers into the EngD programmes, was pointed out.

Capturing impact between the IDC, the industry partner and REs

- The EngD impact is found at the *individual level (REs and EngD alumni)*, *organisational level (sponsoring companies, universities and IDCs)* and at the *sector level (higher education, industry)*.
- Whilst the focus of this study was the impact on industry partners and EngD alumni, there needs to be a better understanding and evidence of the impact of the EngD on the academia, including innovation in education and training for industry; new forms of teaching and engagement with PGR students and impacts on other levels of programmes (e.g. undergraduate, taught Masters, CPDs), as well as new forms of collaboration across different universities.
- Industry partners benefit from inter-university collaboration through the IDCs as they could tap into a broader range of academic excellence.
- Some industry partners have more regular and rigorous approaches of monitoring the progress of the EngD projects, including short-term impacts. Some of the sponsoring companies are embedding the REs as part of their organisational mechanisms, for example, through reward and recognition mechanisms.
- Individuals within the industry partners, including industry supervisors and those managing the university collaboration, seem to have the key role in rolling out the impacts from the EngD projects within and beyond the organisation, and communicating the benefits from the programme in collaboration with the IDC and the AEngD.
- The day-to day iteration processes and risk management practices within the IDC, between the IDCs and the IDCs and companies, are “hidden” from the impact analysis, but these are critical processes for the successful implementation of the projects which need capturing.
- There is difficulty for academic supervisors and for the IDCs in tracing the impact of the EngD projects once the students have completed the programme. Mid to long-term monitoring mechanisms to capture the impact of the EngD projects and the programmes need to be developed between the industry partners and the IDCs after the completion of the projects.

Communicating impact and a need for a joined-up approach to evidence-base

- The EngD alumni would be a vital agent who can communicate the value and impacts of the EngD to the existing REs and potential EngD students as well as to industry.
- Effective data collection on the alumni career pathways and progression, and maintenance of such data is one of the key areas that the EPSRC, IDCs and the AEngD could collaborate and build on further evidence on the impact of the EngD.
- The acceleration of the processes to achieve further professional qualifications such as the Chartered Engineer status is perceived by REs to be one of the key benefits from the EngD programmes,
- There should be more communication and information sharing about the impact of the EngD between the IDCs, the professional bodies and Institutions. More data and case studies of the experiences of former REs getting the Chartered Engineer status would be useful.

International perspectives and further lessons

- Recent international works on the careers of doctoral holders highlight the need for “better data on, and more systematic tracking of” career pathways of all types of doctorates (Borrell-Damian et al., 2010). It is therefore appropriate to review the UK doctoral programmes alongside the similar programmes across Europe and beyond.

- A comparative analysis of the EngDs in relation to other collaborative doctoral schemes would be an important area for future investigation. There are examples of systematic data collection on impacts from the collaborative doctoral schemes, especially in Australia and in the US. A brief literature review is provided in the Annex on the assessment of collaborative doctoral schemes in different national contexts (**Annex 5**).
- The EngD scheme provides a format of R&D and skills training which meets the needs of multinational companies both in the UK and internationally. Multinational companies, for example, compare the availability of doctoral programmes and doctoral researchers in the areas of their strategic importance in different countries and select their partner universities. One of the industry interviewees (a large multinational company) mentioned the lack of appropriate doctoral programmes relevant to their strategic areas (e.g. environmental sustainability) available at the UK universities.
- Many IDCs seem to recruit international students, through a variety of funding mechanisms. However, the international nature of collaborative R&D, destinations and career trajectories of these international EngD graduates are not captured systematically.

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Annex

1. Review of the 18 IDCs mid-term review reports

The IDC mid-term review reports provide a set of information on the various dimensions of outputs, outcomes and impact from the IDCs set up in 2009. The project team reviewed 18 mid-term reviews, submitted from the 2009 cohort of the IDCs in May 2011. There were 19 IDCs funded in 2009 as one cohort. One of the IDCs does not give an EngD degree (it gives a DPhil), and is not a member of the AEngD. Therefore, one of the IDCs was not included in the study. In 2009, a further seven IDCs were created, broadly in the manufacturing areas, but mid-term reviews are not available from these seven centres. In **Table 7**, the list of 18 IDCs are presented.

The information relating to the impacts of IDCs in industry and outcomes from REs is presented in several different parts of the mid-term review (see **Table 8**). Furthermore, each IDC presented their industry impacts differently, with different sets of information and evidence. This made the systematic analysis of the impact from the mid-term review difficult. There are academic and research driven outputs reported in the mid-term review as part of the EngD programme, such as academic publications, conference papers or presentations. Information about the destination of the students is provided in the mid-term review and information about the students' awards, publication and conference presentations. Each centre was asked to provide up to three industry testimonials from their industrial partners. These provided valuable information about the impact of the centres perceived by their industry partners.

Some centres were established in 2009, meaning at the time of the submission of the mid-term review report in May 2011, they were in their second year of operation. It is not surprising that the information about impacts is rather limited in these cases – for example, the first cohorts of REs are just about to complete their programme this summer, in 2013. The timescale of the mid-term review - 18 months after the inception of the 2009 IDCs, only captures short-term impact, whilst some long term impacts from EngD projects could be seen over 5-10 years, depending on the nature of research area, technology and market characteristics. Those IDCs which had been funded before 2009 tend to include impacts from early years - some explicitly mention in their mid-term review, others more inexplicitly. This, in particular, makes consistent understanding of impacts from the mid-term review difficult.

Overall, as a source of information, the mid-term review reports from 18 IDCs have a number of limitations. However, these sets of documents provide a useful overview of outcomes and outputs from the IDCs and serve as a starting point to analyse impacts from the EngD/IDC.

Table 7: The list of the 18 IDCs.

Centres	***Host University/ universities***	***Year(s)***
Biopharmaceutical Process Development	Newcastle University	2009~
Bioprocess Engineering Leadership	University College London	1999~ 2009~
Centre for Digital Entertainment (CDE)	University of Bath and Bournemouth University	2009~
Centre for Innovative and Collaborative Construction Engineering (CICE)	Loughborough University	1999~ 2009~
Efficient Fossil Energy Technologies	University of Nottingham, University of Birmingham, and Loughborough University	2009~
Formulation Engineering	University of Birmingham	2001~ 2009~
IDC in Systems	University of Bristol and University of Bath	2006~ 2009~
Large-scale complex Information Technology systems	Universities of York, Oxford, St Andrews, Bristol, Leeds	2009~
Micro and Nano materials and Technologies (MinMat)	University of Surrey	2005~ 2009~
Molecular Modelling and Materials Science	University College London	2006~ 2009~
Nuclear Engineering	University of Manchester, Imperial College London	2006~ 2009~
Optics and Photonics Technologies	Heriot-Watt , Glasgow, St Andrews, Strathclyde and the Scottish University Physics Alliance	2001~ 2009~
STREAM: Industrial Doctorate Centre for the Water Sector	Cranfield University, Imperial College London, University of Exeter, University of Sheffield, Newcastle University	2009~
Sustainability for Engineering & Energy Systems (SEES)	University of Surrey	1993~ 2009~
Technologies for Sustainable Build Environments (TSBE)	University of Reading	2009~
Transport and the Environment	University of Southampton	1999~ 2009~
Urban Sustainability and Resilience	University College London	2009~
Virtual Environments, Imaging and Visualisaiton Centre (VEIV)	University College London	2001~ 2009~

Table 8: IDC Mid-term review – sections and questions related to the impacts to industry and RE careers

1.2. How has the IDC demonstrated added value (e.g. value for money, comparisons with a standard doctorate) and in what ways has the IDC programme benefited from its larger scale?
2.5. How are students better equipped to be the future leaders in their field and/or act as 'agents for change' in their organisations?
3. Impact in Industry:
3.1. Number of extra Doctoral studentships generated as a result of the EPSRC-funded cohort (e.g. employed students)
3.2. Please give details (no more than 50 words) of all projects, plus details of project partners and their contributions (cash, in kind etc) in Annex ; please give 3 Industrial Testimonials in Annex 2.
3.3. Details of any Business Processes changed for industrial partners as a result of the collaborative research project
3.4. Details of any benefits in time-to-market as a result of the collaborative research project
3.5. How have you engaged end-user partners on steering/strategy committees?
3.7. Any other outputs (e.g. patents) that you wish to report?
5.2. How has the IDC leveraged additional direct or in-kind funding?
6. Impact in the wider community
6.1. What impact and interaction has the IDC had in the wider community, including other research organisations, industry, business, the public and society? Have there been any wider policy, strategic or social impacts arising from or influencing the direction of IDC activities?
6.3. How has the IDC helped to bring about new collaborations in other research organisations, industry, business and society, including internationally?
6.4. What wider initiatives have been set up as a result of the presence of the IDC, including those with other research organisations, industry, business and society?
7. Outputs from centres
7.1. Please give details of the first destinations of IDC students who have completed to date (for on-going Centres, include the last 3 years data)
7.2. Are there any interesting case histories of students moving to excellent and/or unusual careers, directly stimulated by the IDC model of support of benefit, to the UK?
7.3. Please give details of some research highlights arising from IDC projects
7.6. What Intellectual Property e.g. patents secured, spin-out companies, other commercialisation etc, has been generated to date and what has been the impact of these outputs?
7.7. What subsequent funding from EPSRC, other Research Councils, industry, business and research charities would you ascribe to the IDC?
7.8. What other steps have been undertaken to publicise the outcomes of Centre outputs, including 'branding' the IDC model of the EngD qualification?

Table 9: Forms of and routes to impacts – examples from the IDCs Mid-term review

Source: 18 IDC Mid-term review report (May 2011)

IDC	*Individual REs – Career paths and Impacts*	*EngD projects leading to impacts within existing Industry partners*	*Other Impact going beyond the sponsoring company and wider social impacts*
A (a former EngD Centre since 2006)	1) 3 REs were employed after completing EngD; one RE awarded a Knowledge Fellowship to continue her research; one got a job in nano-technology company and one recruited in Investment Banking. 2) REs receiving awards	1) Although projects focus on developing fundamental understanding of general principles, there are specific new products or techniques and benefits to time-to-market directly 2) New method leading to investment more than £500K; patent applied 3) Managerial experiences for early researchers as industry supervisors	1) Spin-out company won the 2011 Shell Springboard competition. 2) Royal Society Industry Fellows joined the IDC to work with industry partners 3) Strategic alliance between the University and industry partner 4)Former research collaboration with international research organisations [US Pacific Northwest National Laboratories; collaborative research and training centre in Ghana]
B (a former EngD Centre since 2006)	1) 2 REs were part of the team that won a Chairman's Award for Innovation in 2008 2) 2 REs remain with their sponsors; one as a Higher Research Scientist, higher level than a normal PhD graduate in permanent employment; 3)one has been retained by his sponsoring SME, funded via KTP 4) 1 RE got a job with the British Transport Police by using his scientific skills 5) 1 RE awarded 1851 Industrial Fellowship	1) Enables advances in design and enhance UK-led collaborations with its US parent company 2) Advances in fundamental understanding of materials and enable to reduce product development cycle time 3) Increases its agility in responding to customer requirements 4) "significant input into improving our expertise that will benefit the aerospace and associated industries"	1) IDC brings about new collaborations in other research organisations, industry, business and society, including internationally industry, for EngD projects could provide new opportunities and improve interaction with the "community". 2) "This project delivers what industry wants, to their longer term needs, activities and ambitions. Moreover, it could change industry's thinking and ultimately their work practices." 3) Accredited course leading to CEng status 4) Influence networks via sponsors and KTNs
C (a former EngD Centre, dating back to 1993)	1) In the recent cohort (in 2007), 7 out of 11 are employed with sponsoring companies; one hired by another company; one got PDRA position in industry. 2) Out of 16 earlier cohorts of REs (start years 2003/4-2006/7), 15 work in industry and one works in academia. Seven continued with the sponsoring companies. 3) Earlier EngD alumni (since 1997) career include Head of Climate Change at X; Manager at X; Manager responsible for Supply Chain Social and Environmental Responsibility. 4) One former RE set up a consultancy and project development company, in 2007 (about 4 years after the EngD), combining experience of the energy solutions and construction markets to make low carbon communities happen.	1)Sponsoring company saved £0.9 million in 2009 and £2.4 million in 2010 2) led to development of codes of practices for suppliers 3) led to the environmentally-sound product design for self-chilling cans 4) RE' work showed "saving of £1million over 5 years for an up-front investment of £50K" 5) the development of techniques incorporated into design decision-making at the firm 6) work being recognised by EU policy makers as well as top management within the sponsoring company 7) RE's work led to the development of codes of practice for suppliers	1) A collaboration with other UK Universities to bid for research 2) Future Collaborations: the IDC has been sought by international universities to set up similar programmes

Contexts and the diversity of the IDCs

The contexts and the diversity of the IDCs need to be borne in mind in understanding the forms of impacts. In terms of the environment and organisational contexts, the following factors affect the processes and nature of the impact.

Nature and the characteristics of each IDC seem to be one of the key factors for the way impacts are *captured*, *presented* and *disseminated*.

- History – EngD Centre 1992 onwards and/or IDC since 2009
- Single university or multiple universities
- Single departmental or multi-department/school/faculty
- Communication strategies of the EngD Centre/IDCs

For example, seven out of 18 IDCs were newly funded in 2009 and only had existed for 18 months at the time of the submission of the mid-term review reports. Other 11 IDCs had been funded over years as the EngD Centres, with larger networks of industry partners and RE alumni. The forms and extent of the impacts are affected by these contextual factors.

The IDCs cover multiple disciplinary research areas (Godfrey, 2012). Some IDCs focus on specific targeted industry sectors (e.g. nuclear engineering, water management, construction). Some IDCs have thematic focus (e.g. sustainable energy, transportation, systems in engineering). Several centres are organised surrounding the specific or multiple technology areas (e.g. digital entertainment, visualisation, biological modelling, optics and photonics, formation engineering), some of which constitute so-called "emerging platform technologies." For example, Formulation Engineering IDC works across several industry sectors, from aerospace to food, disciplines ranging from chemistry and maths across the spectrum of materials science and engineering. It is stated in the mid-term report that:

> *The Centre's scientists are able to "see synergies between different industries and fields and transfer expertise and lessons. It is this linkage across sectors that is especially valuable and which separates EngD and PhD cohorts.*

It is also noted that a set of linked EngDs and PhDs are working together with two sponsoring companies, where the EngD is seen as "an important step in the manufacture of …." [Formulation Engineering IDC, mid-term review, industrial testimonial letter].

The examination of the mid-term review led to an identification of the number of influential factors that condition the form and extent of the EngD impacts:

Nature of the sponsoring firm

- Experiences of collaboration with academic (e.g. a dedicated centre/unit/manager for academic collaboration; long-standing relationships with particular institutions/departments/academics)
- Motivation for participating in the EngD
- Size (e.g. number of employees) and history of the firm
- Location of R&D, production/operation, market
- Profitability
- The nature of the core business (e.g. technology driven or not)

The IDCs work with a range of different industry partners. Some IDC emphasise in the mid-term review reports that they have a mix of large firms, SMEs and start-up companies (e.g. SESS; MiNMaT; Large-Scale Complex IT Systems IDC; Optics and Photonics IDC).

In particular, the motivations and strategies of sponsoring firms need further investigation. The EngD programme is used differently by different industry partners. For some industry sponsors the programme is about developing "capability and awareness of long-term strategically important areas," whilst other sponsors state that they use REs to "conduct early in-depth detailed research" (Optics and Photonics IDC, quotes from the EPSRC mid-term review May 2011).

As one of the IDCs states, the EngD scheme offers "substantial value for money in addressing their medium to long-term tactical and strategic research objectives" to those companies that find standard doctorates or alternative collaborative research arrangements, such as KTPs, too expensive. (Large-Scale Complex IT Systems IDC, quotes from the EPSRC mid-term review May 2011, 1.2) Strategies of the industry and choice of collaborative schemes (e.g. the EngD, Industrial CASE PhD, KTP) also depend on a number of other factors, such as timeline of the research objectives and cost of collaborative research.

N**ature of the EngD projects**

- Technological characteristics e.g. emerging 'enabling technology' or established technology areas with structured supply chains
- Core business of the firm or specific part of the business
- Spatial distribution of research expertise – e.g. the existence of the R&D centres in the UK, or not; concentration of research expertise and R&D facilities in certain geographical areas (e.g. London)
- Equipment/facilities – 'equipment intensive' or not

Diversity of the REs' demographic features

The demography of the REs varies between the IDCs. Large-Scale Complex IT Systems IDC and Systems IDC state that many of their students have industrial experiences prior to the EngD, which is seen as the strengths of the RE cohorts. Systems IDC also mention that relatively high ratio (20%) of their REs are already in employment. Nuclear Engineering IDC has four REs who are the employees of the sponsoring company and have no financial support from the EPSRC. Some IDCs are keen to have employees working in companies to be enrolled as REs. In the case of Molecular Modelling and Materials Science IDC, this is helped by Royal Society Industry Fellowship (with Johnson Matthey and AstraZeneca), having a base at the IDC.

Quality control mechanisms and communication between the IDC and industry partners

In order to make successful project outcomes and impacts there are a number of conditions and mechanisms that have to be built into the EngD programme/IDC. The mid-term review asks these in various sections. For example,

- "How does the IDC ensure proper management and quality control?"
- "Explain how the projects are checked for (a) academic quality, (b) fit to the theme(s) of the IDC and (c) the relevance to any external end user demand (specific or generic)?
- How have you engaged end-users' partners on steering/strategy committees?
- How have you managed incorporation of new partners/existing partners dropping out?

Some of the IDCs provide detailed information on these and articulate how they manage risks. For example, Optics and Photonics IDC describes the process in which a potential industry partner had initially been referred to a different IDC with a similar theme. Following the discussion with the IDC, the company came back to the Optics and Photonics IDC "with modified project and improved synergy with the theme."

They also point out the importance of the management structure in making rapid decisions or directions within the framework of agreed policy with the IDC Management Committee. These iteration processes and management practices within the IDC, between the IDCs, the IDCs and companies, are "hidden" from the impact analysis but these are critical process for the successful implementation of the projects.

Routes to impacts

A number of routes impact are identified through the examination of the mid-term review (see **Table 3** for summary and **Table 9** for examples from the IDCs). The four areas of types of activities constituting the routes to impacts (*generation of new knowledge, innovation-related activities, knowledge generation and networks, human capital and skills development*) (See Section 2) are illustrated with a number of examples provided in the mid-term review.

Generation of new knowledge

Academic outputs/outcomes

The mid-term review reports provide information about academic outputs such as conference papers, publications, and other forms of knowledge generation and diffusion from the IDCs. Some of the new IDCs that started in 2009 mention "too early" to have papers published, whilst several of the IDCs which had been previously funded prior to 2009 put the numbers from earlier projects. This makes the data on academic outputs inconsistent.

Increased in-house knowledge and research outcomes

Tangible academic outputs lead to wider impacts - solving industry problems, research results being applied within the firms, and/or beyond the sponsoring firm, (e.g. international academic impacts, national industry applications).

Innovation related outputs and outcomes

Forms of industry outcomes from the EngD projects include new technology, new instruments, new measures, new techniques, and processing, which are reported to have led to impact such as new products, tools, services, and development of new systems and processes. Impact also includes changes in business processes and reduction in 'time-to market' as a result of collaborative research projects.

Time to market and innovative changes

Bioprocess Engineering Leadership [IDC] emphasises the role of REs acting as 'agents of change' facilitating the culture change in the company. This seems to have resulted in changes in business processes within the companies. Reducing the time taken to bring new products to market is seen as a key challenge for bio-industry companies, especially in the health care area. Examples include:

- By using the techniques and methods, the sponsoring company has achieved an estimated 50% reduction in development effort and time.
- adaptation of the microscale automated methods to speed the development of recombinant proteins and estimated labour savings of 80% in a market sector worth $1.5billion.
- The whole bioprocess platforms could help some companies achieve up to a 50% reduction in development time.

Bioprocess Engineering Leadership IDC shows in the mid-term review report, some of the impact cases resulting from the earlier EngD Centre. One of the EngD project outcomes was a therapy that had an estimated value of $20 billion in 2009.

Commercialisation

An exemplar of **a short-term commercial impact** from the EngD project is found with the Digital Media IDC - within six months of RE's appointment one of the projects led to "a sellable product"– as "a stand-alone offering or incorporated into the overall service package." Commercialisation of patents through licensing is one of the routes to innovation. According to the mid-term reviews, many IDCs mention that it was too early at the time of the submission of the mid-term review in 2011 to identify commercial outcome from the IP resulting from the EngD projects. However, several IDCs state patents application or/and award in the mid-term review. Some of them might originate from earlier EngD projects.

- Formulation engineering IDC says three patents have been granted to REs on their thesis work;
- Four other IDCs [CICE; Molecular Modelling and Materials Science; Digital Media IDC; Systems IDC] say one patent was being applied/submitted.
- Optics and Photonics IDC states that nineteen patents (four patents from one project) have been awarded or applied for.

Spin-out companies from the EngD

Several EngD projects have led to the formation of spin-out companies. About ten spin-out companies firms are recorded in mid-term review reports (see **Table 9**).

- CICE IDC mentions that two EngD graduates in 2005 and 2011started their own companies to deliver consultancy work.
- Optics and Photonics IDC mentions: 1) a spin-off company formed to exploit a technology related to the EngD project, which was then acquired by TGS; 2) "a desire …to spinout a company to exploit the technology developed by an EngD project"; and 3) A spinout company to exploit a technology of an on-going EngD project.
- VEIV IDC has three spin-out companies, including "two live spin-outs related to the EngD."
- Molecular Modelling and Materials Science IDC had a spin-out company in collaboration with STFC Appleton Laboratory
- Start-up company in 2007 drawing on the EngD project on low carbon [SEES IDC]

Knowledge networks and collaboration

Strategic research collaboration

Sometimes the "behavioural changes" happen across organisational boundaries when the EngD research collaborative relationships lead to more formal alliances. Examples include formalised relationships between the IDC and industry partners, as well as industry sponsors working together to sponsor an EngD project.

- UCL VEIV IDC mentions that a memorandum of understanding with Arup was signed, resulting from the EngD collaboration.
- Strategic alliance was made between UCL Molecular Modelling and Materials Science IDC and an industry partner, AWE
- Transport and the Environment IDC have facilitated the joint project between the two sponsoring companies and are expecting more collaboration to happen.

IDCs as the hub for collaboration

The existence of a "substantial body of researchers" behind the EngD programme and the IDC is "convincing to industry and also convinces them to remain collaborating in the programme" [LSCITS]. The IDCs act as catalysts to further collaboration.

- EngD research led indirectly to a new Master's course in Project Management with a large pharmaceutical company. The course is based on some of the EngD modules and currently has over 25 staff from the company registered. It will lead to an MSc qualification [Formulation

engineering IDC]. There is further collaboration between the two IDCs sharing training courses – [Formulation engineering IDC] and [Biopharmaceutical Processing IDC]

- Optics &Photonics IDC states that most of their EngD projects are "equipment intensive" and the REs have access to specialist equipment, not only in the university but within industry, while industry partners benefit from using the IDC facilities.
- Some IDCs act as part of the Knowledge Transfer Networks (KTN) in their respective research areas. [e.g. STREAM, Optics and Photonics, Biopharmaceutical Processing IDCs]

Sector-based approaches

In the case of STREAM IDC, one of the key impacts of the IDC is about having the 'voice' with particular engagement with a particular industrial sector - the water management.

> *STREAM offers around £1,500,000 worth of research and talent development each year, representing a sizeable portion of annual industry-wide investment*.

Research projects are driven by "sector priorities, *typically where there is a need to go back to fundamental scientific understanding and priorities*" (STREAM sponsor survey, quoted in the mid-term review). It points out that the sector's Human Resource departments are recognising the "*benefit that the scheme can provide in terms of attracting talent and providing the people we need for the future*."

Internationalisation of collaborative relationships

Several IDCs have made efforts to internationalise their activities through funding international students by industry funding and university scholarships [e.g. formulation engineering IDC; molecular modelling and materials science IDC] , and by developing long-term links with universities and businesses overseas [e.g. Molecular Modelling and Materials Science IDC; CICE; Biopharmaceutical Process Development IDC; Fossil Energy and Carbon Capture Technologies IDC; SEES].These new relationships may partly be the impact of the EngD programme.

Human capital and skills development, mobility and knowledge exchange

REs as agents of change

In the mid-term review Micro and NanoMaterials and Technologies (MiNMaT) IDC summarises some comments from the REs:

> The REs were "*given the freedom to work on mid to long-term problems, being aware of the commercial pressures but not having to respond to them in the short-term. They felt that this gave them the ability to take more risks and try to find more innovative solutions, which would not have been possible if they were subject to the normal company project management processes. They felt that this unique experience, supported by the emphasis given to the parallel development of their interpersonal and leadership skills, would shape their future careers, such that they would be different from other doctoral graduates*."

RE's career paths

Due to the short time after the inception of the IDC in 2009, the information about the EngD alumni career paths is limited in the mid-term review. Nevertheless, some of the IDCs with previous EngD experiences demonstrate the diversity of the career paths of the former REs. For example, one of the IDCs show the diversity of former REs' career paths which includes not only R&D related posts, jobs in engineering industry and academia but also other industry sectors such as business and finance. Some alumni remain connected to the sector by "advising on biotechnology and bioprocess related investments". [Bioprocess Engineering Leadership IDC].

Individual and organisational capability development

One of the recent REs from CICE is quoted for the impact of the EngD:

> "*the ability to demonstrate high quality work and think rationally, very quickly has led to a promotion as Head of Sustainability; something that would not have happened so quickly without the EngD*."

REs are seen as source of knowledge through the research projects and also as part of the team members, contributing and impacting on their business. Nuclear Engineering IDC reports comments from the industry sponsor:

> *"The REs of our organisation are proving to be a valuable resource, providing high-quality research directly through their EngD project, but also playing their part within the overall team, where their knowledge, skill and growing experience is contributing to the broad output of the business*"

The networks of the EngD alumni re-create impacts in the long term for the industry sector as the examples from Centre in Bioprocess Engineering Leadership show:

> "*Our most pleasing case history to date involves two EngD graduates, one in academia and the other in industry, now working together to support both the IDC concept and the UK bioprocessing sector*"

Enhanced opportunities for Continuing Professional Development (CPD)

The flexible provisions of the taught modules benefit the REs, especially those who are employees of the companies (rather than on stipend), who are sometimes based overseas. This would fit the needs of sponsoring companies well, as some companies see the taught modules away from work interrupting the daily work within organisations. Some industry sponsors send their employees to the training courses provided by the IDCs. This could have a broader impact on the organisational capability of the sponsoring companies, through improved skills and knowledge. Optics and Photonics IDC offers "all distance-learning modules" available to collaborating companies "by flexible, subsidised and accredited provision of EngD taught components."

Industry Fellowships/Innovation Awards

The mid-term review reports show the awards and prizes that REs won during the EngD programme, some of which are directly based on innovation related to the EngD projects.

- A number of EngD students are awarded the Industry Fellowship from the Royal Commission for the Exhibition of 1851, which supplements the stipend. The fellowship aims to "encourage profitable innovation and creativity in British Industry by supporting research leading to a patented product or process in conjunction with a PhD/EngD." (e.g. VEIV IDC – 3 Industry Fellowships; MiNMaT IDC; Transport and Environment Institute IDC).
- MiNMaT IDC mentions that two REs (one under IDC; the other pre-IDC) were part of the BAE Systems team that won a Chairman's Award for Innovation in 2010.
- Fossil Energy and Carbon Capture Technology IDC REs awarded "Prize for Best Team Work" under Engineering Young Entrepreneurs Scheme (YES) in 2011
- Molecular Modelling and Materials Science IDC had a spin-out company from the EngD project, that won the 2011 Shell Springboard competition (see below)
- Digital Media IDC had nominations for two Bafta awards for the EngD technology, which was integral to the game's product.

Enhanced people mobility and knowledge exchange

Some of the fellowships are targeted to enhance mobility of people between industry and academia. This happens in two ways where the EngD programmes/IDCs work as a focal point of interface. For example:

- Royal Society Industry Fellowship (with Johnson Matthey and AstraZeneca), allowed two industry professionals to have a base at the IDC [Molecular Modelling and Materials Science] to participate in the EngD programme as employees of the firms.
- Royal Society Industry Fellowship (with Johnson Matthey) allowed a young academic from Formulation Engineering IDC to work part-time for four years at the company to enhance industry experiences.

Forms of impacts

Economic benefits and financial impacts

Direct financial benefits from the EngD projects

In addition to those already mentioned, a number of EngD impact examples related to direct financial benefits are presented in the mid-term reviews, as well as in the testimonial documents from industrial sponsors.

- the IP generated from the EngD project led to the assets in the trade sale of the company [VEIV IDC].
- to have saved the sponsoring firm £0.9 million in 2009 and £2.4 million in 2010 [SEES].
- the work showed saving of £1M pounds over 5 years for an up-front investment of £50K [SEES IDC]
- (due to the acceleration in time to market [see above]) estimated labour savings of 80% in a market sector worth $1.5 billion [Bioprocess Engineering Leadership IDC].
- a sponsoring company investing in £500K on a new delivery system based on the EngD research [Molecular Modelling and Materials Science IDC]
- a patent application for a new underwater turbine design – will save potentially £300K a year [Systems IDC]
- A new approach to project-based support service delivery helped an IT systems implementation of a multi-million pound improvement for the business [CICE IDC].
- The resultant throughout saves us £1 million per annum [Formulation Engineering IDC, testimonial letter]

Economic benefits of the EngD

One IDC states the "added value" of the EngD in financial terms as follows (mid-term review, 1.2):

- *The average cost to EPSRC per RE is £90K*
- *The average cash contribution per RE from industry is £61K*
- *The average cash contribution per RE from the university is £6K*
- *The average declared value for typical project is £92K*
- *The total additional average declared contribution per RE is £159K*

The IDC states that accurate and rigorous real in-kind contribution is problematic due to confidentiality issues and variable accounting processes.

Another IDC states (mid-term review, 5.2)

- *The EPSRC investment £4.5 million*
- *Cash contribution from industry of £1.93 million*
- *Estimated in-kind contribution in excess of £20 million (£40K per RE per year, a figure generated from data provided by industry in the grant application for the second tranche of centre funding) [sic]*
- *£33.7 million of additional research council, industry and government funds, including research contracts over 2000-2010*

Value for money

Comments from the industry partners are quoted in the IDC mid-term review. The following three quotes from different sectors illustrate the value that the EngD programmes add to the sponsoring companies, either at an individual level [MiNMaT quote] or by adding value to the organisational in-house capability and knowledge [Nuclear Engineering IDC], and the process over time [Optics and Photonics].

> "*Our RE represents excellent value for money. He has proved to be an excellent, highly motivated member of group*." [MiNMaT, mid-term review, industry sponsor comment]

> "*increasing our organisation's in-house expertise in the area, which means that more project work can be undertaken internally rather than being outsourced at significant expense, with the added value of retaining this decommissioning knowledge within the company.*" [Nuclear Engineering IDC, industry sponsor comment in mid-term review]

Optics and Photonics mention that seven companies have funded three or more REs with them and that the "repeat business is an important endorsement" which demonstrates the value of the EngD programme.

> *"In general we find that the benefits of the EngD programme to our company is at least as great as the time and money invested."* [Optics and Photonics, industry sponsor comment in mid-term review]

Additional funding generated through EngD

In addition to the financial benefits stemming from the EngD projects, the EngD catalyses generation of further external income from a variety of sources, including the EPSRC, TSB and other businesses and organisations. Some of the examples presented in mid-term review reports, which include funding generated by previous EngD Centres, are as follows:

- a spin-off research project (with a value of £591,600) 50% funded by TSB) [TSBE]
- TSB grant for the UK post-production/special effect communities (value £500,090) [Digital technology]
- inward investment in London [VEIV]
- a provision of £1.148 million from One North East (Regional Development Agency) was discussed [Biopharmaceutical Processing IDC]
- RE able to use his research outputs to secure £0.5 million worth of funding from his sponsoring organisation to set up and develop a new business venture [CICE]
- EPSRC grant India Bridging the Urban Divide £2.6 million [Fossil Energy and Carbon Capture IDC]
- EPSRC Nanotechnology Grand Challenge £3.1 million [MinMat]
- EPSRC Centre for Emergent Macromolecular Therapies £5.2 million [Bioprocess Engineering Leadership IDC]

Broader impacts – Indirect impacts, behavioural changes, organisational changes, policy change

As already mentioned, REs are seen as 'agents for change,' triggering a number of changes within the company and making behavioural changes within the organisation. These changes are often difficult to quantify but are appreciated by the industry partners.

Indirect impacts

There are less tangible outcomes from the EngD that are identified in mid-term review reports, some of which might take a long time to lead to any direct or indirect impact from the project –

- "advances in understanding of the research area",
- "generate new ideas and challenges to existing processes and methods which will generate change over the longer term"
- "new paradigm of data analysis"
- "agile response to research opportunities" leading to new industry collaboration,
- "agility in responding to customer requirements"
- "developing capabilities and awareness of long-term strategically important areas"
- changes in business practices and processes in different sectors such as "efficiency in the game production pipeline", "making better decisions in medical planning."
- "traversal of one piece of research from one domain to another" that may lead to commercial impact (e.g. from rendering to cosmetics R&D contracting direct consultancy to establishing a research prototype in their laboratories – VEIV)

Policy change, development of codes of practices, influences in the sector

There are direct and indirect societal changes resulting from the new knowledge arising from the EngD projects, both short-term and mid/long-term. For example, CICE IDC reports early outcomes from the EngD projects, including:

- the research outcome has been used by the highway agency to revise their maintenance strategy;
- the Construction Skills Network utilises research results from the EngD and develops further research contracts;
- application of an early research outcomes leading to a reduction in energy consumption within the office.

Sustainability for Engineering and Energy Systems [SEES] IDC has made a "significant impact on the study of sustainable supply chains" throughout the decade of running the EngD Centre. Earlier work includes developing processes for a large multinational ICT company, processes for involving stakeholders in setting environmental and social parameters, which was developed further by another EngD project applied in retail supply chains. Another example from SEES IDC is a former RE whose EngD project was about integrating environmental measures into mainstream business processes, "working to change the culture and encourage people to understand and implement issues." The RE stayed in the sponsoring company, a large multinational technology manufacturer, and engaged with European environmental legislation and now manages supply chain social and environmental responsibility. Urban Sustainability and Resilience IDC states that through the projects they have developed relationships with NGOs in terms of the work of the students, especially in developing countries.

2. Semi-structured Telephone Interviews

2.1 Background

There are two targeted stakeholders in terms of understanding the impact of the collaborative doctoral programmes - individual REs and industry sponsors. By integrating the two perspectives, this study provides multiple dimensions to the understanding of the impact from the programme.

A limited number of interviews was conducted with voluntary respondents, including

- **20 RE alumni** (across eight IDCs and one EngD Centre) and
- **15 industry contact persons** (across 11 industry sectors and specific organisation types)

- Telephone interviews (average duration 30 minutes, recorded and transcribed) were conducted between June and August 2013.
- In consultation with the AEngD Steering Committee sub-group, it was decided to ask the IDCs to provide direct introduction to the alumni and key industry contacts, and initial contacts were given by six of the 2009 IDC cohorts and one EngD Centre.
- Industry contacts were made through the IDCs, and also by directly contacting individual firms with repeated experiences of EngD programmes.
- The EngD Impact study was publicised through the AEngD website, Newsletter, and CBI Intercompany Academic Relations Working Group (ICARG) Mailing List through which a few interviewees (both alumni and industry) volunteered.

Table 10 Industry interviewees

Sector/nature	*No of Interview participants*
Manufacturing	3
Pharmaceutical	1
Engineering Consultancy	2
Energy	2
Water management	2
Nuclear member organisation	1
Public research organisation	1
Consumer Goods	1
Retail	1
Geoscience	1
Total	*15*

Firm interviewees include Head of academic liaison, Head of Technology and those who have supervised EngD project as industry supervisors, those who manage collaboration with universities, including EngD, PhD and post-doc staff. Many of the industry respondents have had close engagement with IDCs/EngD Centres, for example, being an active member of the advisory board of the centres.

Interviews are limited in terms of scope and representation. For example, as the study targeted firm representatives with repeated EngD experiences, most of the industry interviewees are from large firms, which give certain bias to the study. Whilst the findings of the interviews are not generalisable, they provide views of the firms with experiences of the EngD projects with certain diversity in industry sectors.

Table 11 Alumni interviewees; years of industry experiences before and after EngD

IDC Sector	*No of Interview participants*	*Before EngD Fresh graduate*	*Before EngD with more than 3 years Industry experience*	*After EngD Over 5 years*	*After EngD Less than 5 years*
Manufacturing	**9**	5	4	3	6
Sustainability	**2**	2		2	
Systems/Engineering Consultancy	**1**		1		1
Construction	**1**		1	1	
Nuclear manufacturing	**2 (+1)**	1	1		2
Water management	**1 (+1)***	1			1
Micro and Nano Materials	**1**	1			1
Optics and Photonics	**2 (*)**		2		2
Formation engineering /Consumer goods	**1**	1			1
Total	***20 (+2)***	*11*	*9*	*6*	*14*

NB: (Two alumni didn't participate in interview, but sent written responses to the interview questionnaire); (one of the two from Optics and Photonics are in the final year before submission; those from the water management are the final year before submission)

Out of 20 interviewees, 11 are from the 2009 cohort IDCs, with varying lengths of operation. The oldest was established in 1993 (two interviewees were from the earliest cohort) and the most recent ones were established in 2009, with the first year cohort just completing their programme.

In order to understand longer term impacts and to gain contacts with broad ranges of REs in manufacturing settings, additional contacts have been sought through one of the old EngD Centres (Manufacturing), which was originally set up in 1992 but is not part of the 2009 IDC cohorts. We targeted those who enrolled in the programme after 2002/3 for the comparability of the nature of the programme. Out of 20 who were approached from the EngD Centre's list, 9 responded to answer the telephone interview.

2.2 What the industry sponsors say

The nature of the EngD partner relationships varies, depending on the areas of research, technological specificity, the nature of the project, as well as organisational strategies of the sponsoring firm.
During the telephone interviews the research team asked the industry partners about their motivations, why they participate in the EngD/IDC programme and their perceived impacts from the EngD programme. Questions were asked about how these impacts are evidenced by the sponsoring firms. Industry interviewees were asked how they compare the EngD with other collaborative programmes, such as Industrial CASE PhD and Knowledge Transfer Partnerships (KTPs).

Motivations of industry in participating in the EngD programme
As one of the industry interviewee puts it

> *"The basis of why we have EngD could be linked to a business need or programme, so whenever we set that up [the EngD projects] we've identified where we want to get to. That's all part of how we evaluate the direct impact of the EngD."*

The nature and the aim of each EngD project differs according to the motivation and objectives of the sponsoring firms, which would shape their perception and evaluation of the 'impact' of the EngD.

Each IDC has a number of sponsoring firms that host the doctoral projects. There are many industry partners who repeatedly sponsor EngD projects (EPSRC, 2007). Several of the industry interviewees are from those repeating sponsors. Several industry sponsors from the manufacturing sector, with extensive experiences of the EngD projects, pointed out that the EngD programme is unique because of:

1) the "portfolio of the projects" compared to the specialised nature of the PhD; and
2) the time spent within the industry and the direct contacts and
3) the control they have over the nature of the project.

Sponsoring firms act as a research sponsor as well as a potential employer, in many cases. The majority of the industry interviewees - 10 out of 15 industry respondents (67%) - mention that one of their motivations for engaging in the EngD programme and sponsoring EngD students is to use the programme as a tool for employing key talents. Two of the industry interviewees stated that the EngD project acts as "4 year interview process", one of them commenting that 80% of REs are hired after the completion of the programme. These responses are from Water Management, Manufacturing, Engineering Consultancy, Pharmaceutical, Public research organisation and Energy sectors.

A few sponsoring firms [Energy, Consumer goods] see the prime reason for participating in the EngD programme as a specific way to collaborate with academic institutions on a particular research area, while they are open about the possibility of recruiting when there is a matched need. One respondent [Consumer Goods] states that they use the EngD project as "a buffer," using external doctoral students to respond to the specific research needs of the firm and they think the EngD gives "flexibility" to manage the changes. One industry sponsor [Energy] sees the EngD programme as a way to tap into state of art research expertise through doctoral projects, which is more common in other countries where they sponsor PhD students who work within the company. There is one industry sponsor [Retail] that is clearly separating the EngD from their recruiting processes, which is done through the graduate recruitment scheme. They see the EngD projects as direct solutions to their industry problems and highly appreciate the impact from them

but they don't see the REs as future employees, as the areas of the projects are specific and not the core part of their business.

Routes to industry impacts

<u>New knowledge generation</u>

Increased in-house knowledge and research outcomes that can include a combination of different things**,** such as a creation of new knowledge, solving industry problems, research results being applied within the firms, and/or beyond the sponsoring firm, (e.g. international academic impacts, national industry applications) and publications.

> *"[The impact of the EngD]… can be a combination of things; the delivery of necessary new scientific insights, or evaluations or development of evaluations of tools, methods and approaches; but it can also include publications and getting the information out there" (Consumer Goods).*

Developing and testing a new instrumentation method, new processes have been mentioned, as the EngD impacts on different sectors (Manufacturing, Retail, Energy 1, Consumer Goods, Public research organisation).

> "*Through the EngD we're looking at finding new processes and new technology. We're also looking for new contributing techniques for producing new products, but not really for new products, because we're not that kind of company. We're also oriented towards developing and testing new innovation*." (Manufacturing 2)

Industry problem solving, new modelling tools and financial impacts

A big UK-based large retail company has recently hosted two EngD projects to look for "new technologies, developing/testing a new method of innovation." Within two years, one of the projects resulted in the development of "modelling tools for calculating energy consumption of buildings." The new modelling tools have been implemented in the company's UK stores, as well as its overseas stores, resulting in "substantial cost savings of nearly £5 million."

> *"The RE did a project about energy efficiency behaviour about 13-14 months ago; we did a roll out through all the stores across UK, involving 300,000 people. Electricity consumption is quite significant, and we were looking at electricity consumption savings across the UK. Within 18 months of the start of the EngD project we managed to come up with savings worth several million pounds; the RE already helped deliver that as a benefit."*

The experience of this Retail industry sponsor seems to suggest that immediate 'rolling out' of the initial EngD outcomes has led to a much bigger scale impact:

> *Over the last six months this process has also been rolled out to Asia; we're forecasting that it will be about £3 million worth of savings this year, on top of UK figures. I think this model has a few per cent more savings over the previous one we had. It's a very exciting journey. We've used it in trials in the UK and then rolled it out in different countries; they applied it in different ways but the fundamentals remained the same. This project alone could save us approximately £5 million"* (*Retail*).

This example provides 'quantified' evidence of immediate and significant financial impacts to the industry from the EngD project. It should be noted that as the nature of this firm is not scientific or technical, the

EngD is seen as a great programme that allows expertise to be brought in to solve business problems. The company does not see the EngD as a recruitment route, however.

Long-term approach to technology problem solution and business change
For some industry sponsors interviewed, investing four years in research is considered to be too long and slow a process and tensions with the fast-moving business environments are recognised.

> *"Achieving research through PhD studentships or EngD studentships in four years, they're quite slow in terms of having output that's exploitable, which doesn't always fit well with the finance community, who are always looking for short-term benefits. You need to pick topics that have immediate-term benefits." (Manufacturing 2)*

However, other industry sponsors take a long term perspective with the EngD projects:

> *"It is a mid-term and long-term solution. Because we started (supporting EngDs) 10 years ago, we are seeing rewards now." Those (companies) who start now, it is not going to solve today's problems, but it is well worth it." (Manufacturing 3)*

> "*The way we've used the EngD is to support the business change programmes that we're interested in. It works because of the four-year programme; if it's too short it'll be a wrong vehicle to do that. By definition, the things we look at are longer term." (Consumer Goods)*.

Innovation
New business processes and future strategic changes
A few of the industry partners believe that using the result of the EngD programmes can lead to new business processes, and furthermore, broader impact across the sector, both direct and indirect:

> *"The EngD programme is more like a speculative way to ensure the long term impact. In fact, there have been changes in supply chain management and this has already been implemented in future policies." (Consumer Goods)*

> *"… It [the EngD project] can definitely change business processes in industry-related standards and new approaches." (Water 1)*

Technological development, such as new software and processing, may lead to new products and new markets. Due to the high costs and limitation of resources in an early stage of technology developments, it is often difficult for companies to develop new technologies. The industry interviewee states that an RE in his firm managed to find a new process in terms of security application which helped the firm to expand into new business territories and markets.

> *"The EngD can be used to kick-start new technologies." (Geoscience)*

Consequently, some part of the technology from the EngD project resulted in a spin-out firm from the sponsoring company.

When applicable, some of these technologies are patented or protected through other IP mechanisms. The IP that derived from the EngD projects stays with the sponsoring company, which is seen as one of the advantages of the EngD programme.

Knowledge networks and collaboration

EngD as a Mechanism for Sector-wide Problem Solving

In a particular technology area (e.g. optics and photonics) the technology development from the EngD and its wider impact are seen as an important part of the 'technology supply chain'.

> *"We are trying to maintain our technology supply chain ...the EngD is an important part of that. Social and economic impact of the EngD is a very important component of the technology supply chain."*

The impact of the EngD is recognised as sector-wide, beyond individual projects and technologies.

> *"There is a long time gain for the sector through the sponsoring firm, not just individual EngD and technical impact…..Through the IDC management board meetings, a number of industries come together and when common areas emerge we can do a joint funding….." (Energy1)*

The University knew sponsoring firms and suggested joint projects – this is seen as "*a real synergy and an added value of the IDC."* For example, in a new EngD project with the IDC in Nuclear Engineering, two companies work together in a collaborative funding of the EngD project. One company provides an industry problem and another company funds the project where their commercial tool gets validated. The RE will spend 50% of their time at each of the companies.

Another example is where the IDC focused on water management. The IDC was designed as a sector-wide approach to improve the UK water management industry. Through the IDC, collaborations between the sponsoring companies were established, along with five universities working collaboratively. The universities and industry partners shared facilities and capabilities and co-sponsored the EngD projects.

The IDC in sustainable environment technology [SEES] has co-sponsored the EngD projects with several aerospace industry companies. Transport and the Environment IDC has also facilitated the joint project between the two sponsoring companies and is expecting more to happen.

Collaboration with Academia

One industry respondent sees the EngD as a key instrument in delivering science technology in the industry relevant context.

> *"We run the industrial aspect of the EngD as an integral part of our science and technology development. It's a means to deliver the science and technology findings." (Consumer Goods)*

One industry partner commented that in addition to the fact that the RE is co-located within the firm, 'geographical proximity' to their local IDC is essential in order to have access to excellent academic research and interactive opportunities, including the use of facilities and consulting senior academics.

> *"We are very keen for our local IDC to continue. Proximity is important. Students are co-located with us and, also, we tend to have close links and interact with the centre and academics. That is the direct value of the programme, being around and being networked. When another research opportunity comes up we want to be on their mind and be part of the research. When you do technology research it is very difficult to get funding. It is great to have a university close by – I can take a half a day and work with the university. This is much more cost effective. We are very fortunate as the local universities are world class [in the research areas with which we work]."* (*Manufacturing 1*)

The EngD programme is seen as the critical catalyst for such collaborative relationships.

Human capital development

Employment

As already mentioned, the majority of the industry respondents (10 out of 15 industry respondents) who participated in the interview consider the EngD programme as a recruitment route. One of the interviewees said that in his organisation approximately 80% of the REs were recruited upon the completion of the EngD programme:

> *"I was always very keen to have EngD students in my team. They are more embedded into the commercial part of things, and this is very helpful." (Engineering Consultant)*

In different industry sectors, similar comments were repeated:

> *"Employment could be the most important outcome of the EngD. This is because you are looking for people for your business, with a long-term employment perspective." (Public Research organisation).*

Some industry sponsors see the REs as not only future employees but potential future managers:

> "*REs are seen as future employees.... We do have a view of employing people with a long-term perspective*." (*Water 2*)

> "*We look at them as potential employees, and also managers, provided they meet the requirements to be future leaders." (Manufacture 2)*

There is a view that the EngD programme enhances talent development as a sector.

> *"I think there is a shared view in the water sector that the EngD is a good way to train up new skill sets for the graduates, which will result in an enhanced talent pool." (Water 2)*

Skills development and organisational learning

One industry respondent called the EngD an "internalised learning process."

> *"EngD projects enable choice of certain technical areas, increase confidence, take the learning forward, through knowledge transfer between the student and supervisors through the internal process, creating synergetic effects. Supervisors are part of the learning cycle."*
> (*Energy 1*)

The EngD projects enhance learning processes within the sponsoring organisation, beyond REs. The EngD project enhances the skills development of the existing employees, including industrial supervisors.

A sponsoring company sees the EngD as a low risk mechanism for long-term skills development.

> *"The EngD student is a good way to do that because the EngD is a lower risk due to the funding by EPSRC……. This could be a way for us to develop long-term planning and skills in certain areas, Also, this is a way to train people. We use it for flexibility, both from top-down and bottom-up." (Energy 2)*

The EngD programmes provide broader learning opportunities for the participating firms. Several industry respondents [*Pharmaceutical, Consumer Goods*] commented that they send some of the staff to part of the EngD short taught programmes as professional development.

2.3 What the EngD alumni say

Individual characteristics and motivation to participate in the EngD programme
As presented in **Table 11**, 20 alumni were interviewed between June and August 2013.

Typology of the EngD alumni was developed. In terms of prior experiences:

1) those without (or less than one year) industry working experience (*fresh graduates*),
2) those who had had working experiences in industry prior to the enrolment of the EngD (*RE experienced*). In terms of destinations after the completion of the EngD,
3) those who stayed on at their sponsoring companies as an employee, and
4) the REs who left the sponsoring companies at the end of the EngD and found jobs in the same industry or in different sectors.

Almost half (9 out of 20) alumni had had more than two years' industry experiences prior to the EngD programme, of which 3 had more than 10 years industry work experiences prior to the EngD enrolment. Of those who were fresh graduates (11 out of 20), most of them had some kind of industry experiences, ranging from summer work experiences to 1 year industry placement, as part of the first degree. Those RE alumni interviewed commented that their previous industry experiences probably helped for the EngD RE selection process even if the areas were not the same.

In the interviews, alumni were asked to choose from a list of suggested 'motivations' – why they launched on the EngD programme. They were asked to choose multiple answers from the list of 'motivations' and 'expectations' as below. Most (18 out of 20) alumni said their main motivation for joining the EngD programme was "**the opportunity to work with the industry whilst conducting academic research**." The commercial aspects and industry-based nature of the scheme are also recognised as main motivations for the REs.

> *"I liked the fact that it was company-sponsored and company-based. It wasn't necessarily a PhD but it was more driven by the industry and concrete industrial problems." (RE Formulation-Consumer Goods, Fresh graduate)*

> *"I had never considered a PhD; it never crossed my mind to do a doctorate because I wanted to get commercial experience.... the thing about the EngD is that you are getting that commercial experience. ... that kind of experience to put in my CV is what I was looking for." – RE Manufacture-Construction Fresh graduate)*

> *"I liked the whole idea of the EngD in terms of educating and framing people to work in the industry rather than just having people purely for research." (RE Manufacture-Milling Experienced)*

> *"The thing about EngD … is that you can research something that can be used by the company afterwards. It's not just general research; it's something that the company can be interested in and take up in the near future. I think it's important to have this application side of it. …Having courses like this as a more cost-effective way for industry to engage with academics for research is really good."*

For experienced REs, there have been concerns over returning to education in the midst of their career. Therefore the EngD, they believe, is the right channel to help them maintain their positions within the industry as there will be no hiatus in their career ladder, compared to taking on a purely academic doctoral, such as the traditional PhD:

> *"I like that the EngD programme requires REs to spend time in the company. You'll benefit from having a position in industry rather than doing pure academic research. This is important for people who are already in the industry (because) it's hard for them to go back to academia." (RE Manufacture-Energy Experienced)*

Another experienced RE put the reason for choosing the EngD as follows:

> *"While I was working (in industry) I started thinking about doing a doctorate. I started researching online for industry-based doctorates.... I enjoyed being in university but I didn't enjoy the academia. So I decided to do the EngD." (RE Nuclear Manufacture, Experienced)*

Typology of the impacts of the EngD as identified by alumni

The interview with the EngD alumni demonstrated both direct and indirect routes to the EngD impacts. Some of the outcomes from the EngD have resulted into some medium to long-term impacts that are not necessarily quantifiable. The complexity of these types of routes to impacts needs to be considered during the process of evidencing impact.

Both tangible and intangible outcomes from the EngD were identified including:

- The EngD Qualification as a route to the impact
- Outputs/outcomes from the EngD projects
- Sector-wide benefits
- Employment
- Career progression and professional recognition
- Further professional qualifications
- Skills and competences

The details of interview results are illustrated below.

The EngD qualification as a route to impact

The gaining of the EngD as academic qualifications is seen as a route to the impact to the former REs. However, no direct causal links can be presumed between successfully obtaining the EngD as an academic qualification and the following outcomes, such as "career progression" and "self-achievement".

According to the EngD alumni interviewed, the EngD degree has aided their professional development following the completion of the programme, especially in terms of developing their career paths. Some of the interview quotes evidence this:

> *"The EngD qualification has helped me advance into better positions within the industry. It has opened some doors, and given me credibility in certain situations where people don't know me but they know I have a doctorate. I think it helps one to be taken seriously..." (RE System-Consultancy, Experienced)*

In particular, the element of **business/management related qualifications** as part of the EngD programme is highly regarded by the alumni as an impact.

> *"(The qualifications) give your CV a bit more volume – especially the fact that you have an EngD as well as a Diploma in Management." – RE Manufacture-Milling (Experienced RE)*

The management courses as part of the EngD programme are seen as having exerted positive effects in their career progression:

> *"It was the management courses (in the EngD programme) that encouraged me to pursue a management career in the company, rather than a technical one." - RE Manufacture-Aerospace4 (Experienced RE)*

> *"The management courses let me strengthen my business abilities and helped me to change my role from R&D to more managerial roles." – RE Manufacture-Technology Engineering (Fresh graduate RE)*

Outputs/outcomes from the EngD projects

Several of the former REs stated that the technology developed through the EngD projects had led to new products or new services. Out of 20 former REs interviewed, the majority said their technology was not patentable, or patenting was not relevant; four said the technologies from their EngD projects were patented. In some cases other IP protection, such as trade secrets, was applicable. Specific examples of the impact from the EngD projects identified in the interviews include:

- **technology** developed through the EngD project was patented and led to the new manufacturing standard within the firm, "delivering innovative manufacturing solutions" to the sponsoring firm; the technology developed is even mentioned in the "annual statement of the technology investment" by the Director of Engineering of the firm [e.g. *RE Manufacture-Aerospace 4*]
- **patent** is one form of technological impact, as mentioned by an experienced RE who produced 5 patents related to his EngD project and his job [e.g. *RE Manufacture-Aerospace2*]
- **a new product** was developed based on the technique from the EngD project, which led to financial impact [e.g. *RE Manufacture-Chemistry 2*],
- **a new business venture/ group** based on the EngD project was set up, leading to financial impact [e.g. *RE Construction-Engineering Consultancy*]
- **a new research area** was developed and received funding [e.g. *RE Materials*] as a result of the EngD
- **a start-up firm** related to the EngD projects [e.g. RE *Optics*]
- **sector-wide problem solving and linkages** [e.g. *RE Nuclear-Nuclear*]

Comments from some of the interviewees who elaborated the impacts from the EngD projects as moving from academic impact to industry impact, leading to indirect financial impact:

> *"Since I could align my EngD projects with higher-level industry projects, it definitely had an impact. ... The major breakthrough occurred in the performance of certain types of laser systems. (My paper) has been published internationally. ... Within the national context, it definitely had an industrial impact. Companies were very much interested and wanted (my research) results. ... (The research) has helped develop confidence that we can approach high laser systems. ... The research did not bring any direct financial impact ... it was more*

indirect….but the impact is that it (the technology) is now internationally recognised." – RE Optics-Laser (Experienced)

The outcomes include **a new doctoral project**:

"Several publications came out a few years ago, also some peer-review articles. I also presented the work at numerous conferences. My research projects have also been used as a base for at least one PhD student to carry on and pick up what I haven't finished. (S)He used it to carry on with the research and it kind of continues…as part of an industry-academic consortia" (RE Manufacture-Chemical, fresh graduate)

The outcomes benefit the RE, the company and the University:

"I had one patent and four publications from the EngD project. Benefit is to give world class innovation to the company that uses it in their business; Helps me develop as a manager in a big organisation and it gives the credibility to the University for the research that it delivers" (RE Manufacture-Aerospace 4, experienced)

One former RE commented on **strategic approaches, systematic reviews and support within the sponsoring firm** that helped the progress of the project and rolling out the impacts.

…..[the EngD project] was very carefully reviewed throughout the whole program. We obviously had our yearly reviews with the industry and university, but separately, on a monthly basis, we were given feedback on our project. When I was working with the project itself, also, on a daily basis, there were other employees who helped us shape the direction of the program (RE System-Consultancy, experienced)

In terms of the **sector-wide benefits**, one RE alumni commented on the direct impact of the EngD project. Furthermore, given the fact that he works within the sector, he is part of the R&D supply chain:

It's beneficial for the nuclear industry as a whole. My research [area]….directly influences the whole of the UK…., …[after the EngD with a new job] My industrial supervisor now works for me. I'm now the customer, so I'm the one who commissions them to do research for me. (RE Nuclear-Nuclear, fresh graduate)

Employment

Of the 20 REs interviewed, all of them were able to secure employment right after the completion of their EngD programmes. 15 of the 20 former REs who were interviewed secured employment within the sponsoring firms where their EngD projects were hosted. This number seems to be relatively high and needs to be compared with a broader data of EngD/IDC alumni destinations. For those interviewed who were not employed by their sponsoring firms, the majority seems to have stayed within the same industry sector related to their EngD projects. Some individuals, however, have ventured into completely different sectors.

Many of the RE alumni positively link the EngD experiences to their employment, as the programme allowed them to be embedded within the firm and to develop their expertise and skills, leading to employment opportunities:

"Although I am now working in a different department (to the department where I did my EngD), the EngD gave me the chance to work and to be embedded in this company, and it definitely developed my career." (RE Manufacture-Engineering consultancy Fresh graduate)

"The EngD is an excellent investment. Companies gain full-time employees at much less cost. Additionally, EngD helps to develop expertise, which leads to employment." (RE Manufacture – Technology engineering Fresh graduate)

"Because I've had a placement here [in the sponsoring firm], I think I'm quite used to the working environment." – RE Manufacture-Aerospace 1 (Fresh graduate)

"[After the completion of the EngD] I was employed on a permanent contract... I enjoyed the type of work I was doing and I know (all of this) was a direct result of the EngD programme." – RE Materials-Composite (Fresh graduate)

Career progression and professional recognition

The REs are specifically asked: "Do you think that the EngD qualification has helped you advance into better positions within the industry?".

A former RE *(Manufacture- Technology Engineering, fresh graduate)* who had been offered a job at his sponsoring company after the completion of the EngD said that the EngD qualification has accelerated his career advancement from R&D to a management position in the organisation.

Another former RE comments that although the starting point would be the same for the EngD and PhD, he foresees faster career advancement:

Well, everyone has the same contract; no one gets a different individual contract. So an EngD would get the same pay grade as a PhD graduate. I'm not in a better position compared to someone who came straight from university with a PhD. However, I do see that in 5-6 years I will progress further, compared to someone who has a PhD, which is the advantage of the EngD (RE Nuclear-Nuclear, fresh graduate).

One of the former REs, who was a fresh graduate, commented on the salary and career progression advantage through the EngD:

I think the EngD is advantageous, compared to the PhD, if you're going into industry. I think PhD has quite a low salary, unless you've got a really good degree. You are underpaid for four-years . ….The EngD bridges that gap in salary. It makes it easier because you're already in the industry. For me, it removed the dangers of spending 4 years earning less, or completing a [PhD] thinking that's four years where you could have earned more or climbed the career ladder. (RE Manufacture-Aerospace 3, fresh graduate)

One alumna, however, pointed out the fact that her four year industry experiences as part of the EngD had not been taken into consideration as part of career progression:

…..it's not recognized as much as PhD. …I've been here for four years and know exactly how [the company] works, and when I got the position within [the company] I was instantly doing my job, there was no induction, no training – none of that. ….it should be reflected in the salaries. My argument with that is if there had been EngD recruits coming from elsewhere I think they would

have needed the same amount of induction, just the way other PhD recruits do. But with INTERNAL EngDs (students who are sponsored by [this company]), the salaries should reflect this experience. (RE Manufacture-Engineering consultancy, fresh graduate)

There seem to be different perceptions, as well as different practices, in terms of career progressions. From the interviews, benefits of the EngD on career progressions across industry over time are not clear.

Those REs who had been employees and sponsored by their firms to do the EngD programme stated that the EngD helped advance their career within the organisations:

As soon as I got my EngD I could apply for promotions, so it had an immediate effect. Since then, more responsibilities were assigned to me. I became a group leader of a very large research group. (RE Optics-Laser, experienced)

One experienced former RE, who had been working in his area of technology over the decades and was sponsored by his employer to pursue the EngD, commented on the effects of the EngD as gaining "more respect" and "recognition":

I think you get more respect and earn recognition if you have a doctorate. So it's for that recognition. I didn't realise that was going to happen at the time. At [the company] you employ so many PhD and EngD students, and you get about 5% within the company who has a doctorate title. Now I use that title myself as well. (Manufacture-Aerospace 2, experienced)

In the interviews, the range of salaries of the REs has also been explored. The initial objective for this question was to compare the average salary of individuals possessing the EngD qualification with individuals possessing the traditional PhD qualification. Attention was given to the number of years worked and the professional role of individuals (whether managerial or technical). However, due to the study's limitations with regards to time and sample size, this pilot study did not manage to gain comparable data-sets on salaries. However, the research team noted that there have been interesting cases of salary increases for some REs before and after the EngD programme.

For example, *RE Construction* said in the interview that after the EngD he stayed on in the sponsoring firm, and by developing the EngD outcomes into a new business unit, through external consultancy projects, his level of earning went up substantially compared to his salary prior to the EngD. RE *Manufacture-Energy* mentioned that after the EngD his level of salary doubled compared to the one at the company where he worked prior to the EngD.

Further qualifications - Chartered Engineer (CEng), MBA

During the interviews, when we asked about the "further qualifications" after the EngD the most mentioned qualification was the Chartered Engineer (CEng). The Engineering Council sets and maintains the UK Standard for Professional Engineering Competence (UK-SPEC). Discipline-specific Professional Engineering Institutions (PEIs) are licensed by the Engineering Council to undertake the peer assessment process according to UK-SPEC standards (Seddon, 2012). Applicants must have the required standard of competence and commitment. For the award of CEng status, they will typically hold an educational qualification to at least Masters level and have several years of workplace professional development. According to an Engineering Council survey in 2011, PEIs supported the view that the EngD may be

recognised as “an exemplifying academic Qualification for the award of CEng, despite the fact that these vary enormously” (Seddon, 2012). Some of the IDCs have got their taught courses accredited as meeting the academic requirements for the Chartered Engineer status.

Two of the alumni REs who had already obtained the Chartered Engineer status believe it was aided by the EngD qualification.

> *“It (the EngD qualification) has helped me garner my Chartered status.” (RE System-Consultancy Experienced RE)*

> *“I became chartered 2 years after joining in the company [after completing the EngD]... and I'm pretty sure without the EngD I wouldn't have been chartered in such a short time.” (RE Manufacture-Chemical 1, fresh graduate)*

At the time of the interview (2013), three RE alumni said they were in the process of applying or working for their Chartered Engineer status (*RE Manufacture-Chemicals, RE Manufacture* and *RE Materials*). One of them commented that the EngD experience was an advantage believing it accelerated the process towards this professional qualification. He believed that the EngD programme was a good pathway to future industry leaders and had helped in the development of his career so far.

> *“One thing I want to do in six months to one year is get chartership. I know the EngD counts for quite a lot of the competences they're looking for. I'm going for the Institution of Mechanical Engineering. I think the EngD being accredited by IMechE helps to get the chartership, and of course it then helps you in your CV and getting jobs and getting promotions and so on.” (RE Manufacture-Aerospace 1, fresh graduate)*

However, there is no overall information available about the number of former REs who have achieved Chartered Engineer status, as the peer assessment process is undertaken by the individual sector specific professional engineering institutions.

Skills and competences

As the EngD programme is organised to meet the demands of both academia and the industry, a question was asked whether the EngD graduates consider themselves equipped with skills and knowledge required by both worlds. During the interviews, the former REs have been given the choices of *business skills, transferrable skills* and *technical or industry-specific skills*. They were asked if they believe that the EngD had enhanced their business, transferrable and/or technical skills.

Business-related skills

The result shows that the majority of the EngD graduates perceive ***business skills*** to be the most important and also believe that the EngD has had an impact in enhancing these skills. As mentioned above, the EngD programme requires REs to undertake business courses as part of the taught programme. The RE alumni were asked whether they believe that the business skills gained from the EngD programme were beneficial to them within their *career*. The result shows that 15 out of 20 RE alumni (75%) believe that the business skills are indeed useful:

> *“You are exposed to accountancy, operational management, legal aspects of HR – so certainly it (the business courses) equip me with the tools I need to enter management.” –*

RE Manufacture-Milling (Experienced, who is currently holding managerial roles within his sponsoring firm)

"The business courses … are really useful and a good foundation during my work. From my perspective, it was a really interesting fact to take engineers, who are very factual and logical, and make them understand how their work impacts on society. We also find that really stimulating. My sponsoring firm now is very customer-focused. So having those foundations learned in EngD is really useful." – RE Sustainability-Water (Fresh graduate, who stayed within the same sponsoring firm and is currently holding a managerial role)

"I think the (business) courses were really good. In terms of marketability in your CV and interviews, there is absolutely an impact. It gives you a language, in order to understand what people are talking about. ... It helps me understand the principles in my sponsoring company." – RE Manufacture-Chemicals1 (Fresh graduate)

RE Manufacture-Aerospace 4, who is currently carrying out a managerial role in a large aerospace manufacturing firm, also mentioned that the business courses have been extremely beneficial. Through the business modules, as part of the EngD programme, he got interested in "management as used in manufacturing industry", which led him to move to a management career after the EngD, via a graduate scheme within the sponsoring firm.

RE Sustainability-Water working in one of UK's largest water companies, stated that the business knowledge gathered from the business courses have been fundamental and useful for her work; especially in terms of understanding the business environment, finances and the psychological factors that drive her employees and her customers' needs.

"(The business skills) are all stepping stones that brought me to the next level." – RE Sustainable-Water (Fresh graduate)

Transferable skills

According to the interviews, the former REs perceive ***transferable skills*** as the second most useful skill that the EngD programme has provided them with. This perception is supported by 14 out of 20 former REs (70%).The alumni told the interviews that they had seen the enhancement in specific skills, such as presentation skills, communication skills, networking skills and so on, during the EngD programme and found it useful after the EngD programme:

"During my EngD I actually believe the general skills were important, especially in terms of coordination and communication. I had to better manage both my industrial and academic supervisors in terms of understanding what they wanted out of the programme and to challenge them whenever I saw appropriate. ... I think the most valuable knowledge I've gained is to "lead by doing.'" – RE System-Consultancy (Experienced)

A current RE, who is close to completion, (*RE Current-Water*) described transferable skills that he has gained from the EngD as follows:

"Problem solving skills, presentation and communication skills, and also 'creative lateral thinking'" (*RE Current-Water, fresh graduate*)

RE Manufacturing-Construction mentioned that the transferable skills obtained from the EngD are useful, which would be useful in any organisation.

"The biggest thing I got was interpersonal skills, such as presentation skills, research skills and so on. It taught me how to think. It taught me how to be careful and go back to the first principles and not assume that because something is always done a certain way then that's how it should be done." – RE Manufacture-Construction (Fresh graduate)

RE Optics-Laser, who is the only international RE (funded by his own employer at that time) in this study also mentioned that the EngD has helped him enhance his transferrable skills by giving him exposure to international groups. Being already working in the industry organisation, he commented that the EngD was the only way for him to pursue a doctorate with industrial relevance, with some training delivered as distance learning modules. In terms of the impact through his research, *RE Optics-Laser* made industrial impact within the South African context (where he is originally from). Further, his research was then quickly picked up by international contractors, as well as other international research groups working on the areas of his technology for their own development. He commented on the impact of the EngD project as well as the benefits on his skills:

"In the UK, the follow-on work led to invitations to talks and conferences. In that aspect, the impact is that the technology is internationally recognised. ... This added to my communication skills ...(it) brought greater exposure to my networking skills." – RE Optics-Laser (Experienced)

Further, other REs have noted that the EngD has enhanced their transferable skills in terms of analytical judgement:

"The problem solving ability; for example, allows for lateral thinking and for me to look at different approaches." – RE Nuclear -Nuclear (Fresh graduate)

"... having the confidence and the knowledge to push-ahead with something, and managing my time. It's all used to understand how to get a result out of your project. ... I've had a very steep learning curve, coming here." – RE Manufacture-Aerospace 3 (Fresh graduate)

"I think the technical skills are the second important, compared to having the confidence and the knowledge to push-ahead with something, and managing your time…understanding how to get a result out of your project and how to present it. … these transferable skills are much more important compared to technical skills" (Manufacture-Aerospace 3, fresh graduate).

Industry-specific knowledge and technical knowledge/skills

One third of the alumni (7 out of 20) believe that the technical skills they gained from the EngD programme are especially useful during and after their EngD. The other 13 REs perceive that technical skills are not necessarily impactful because they are specific to their research areas and, therefore, could only be used within limited areas.

The 7 REs that supported the notion, however, mentioned that the technical skills are useful in their current roles, as they work in technical related areas:

To me, the key is the technical skills/competence. It has enabled me to accelerate in my career more rapidly than what is normal and helped me to put the academic research into industry background. Also, a feature of my project in terms of changes in supervision, managing communication within academia and industry and so on.... these features were a big help.- RE Manufacture-Chemical 1, fresh graduate

RE Nuclear specifically said that the technical knowledge he gained from the EngD is most important to him because he continued to conduct research in his current role, whereby the technical knowledge proved to be helpful. In addition, he said that technical skills are the skills most valued by his employer.

Other outcomes

Throughout the interviews it was noted that a number of former REs were given **academic awards, or innovation awards**, during their EngD programme, sometimes from the university and/or industry. As a result of such awards, the outputs and outcomes of the EngD had wider dissemination routes; for example, international conference presentations, and media coverage.

Furthermore, other themes that emerge from the interview as an impact from the EngD include ***self-realisation*** and ***self-confidence:***

> *"I couldn't give the EngD a higher appraisal, because it made me see this world from a different perspective. It definitely changed my life." – RE Sustainability-Consultancy (Fresh graduate; who has since written a book on sustainability decision-making, a topic related to his EngD project)*
>
> *"The EngD allows you …..to learn from and adapt to things happening around you. It gives you the space to develop as an individual." – RE Manufacture-Milling (Experienced)*
>
> *"Personally, EngD gave me confidence ...." – RE Manufacture-Chemicals2 (Fresh graduate)*
>
> *"I increased my confidence. ... the EngD let me work with the industry, so I got to know how everything is and I realise that I need to be self-efficient. So it gives me a good basis for this". - Current RE Water (Fresh graduate)*

Career pathways

The research team has outlined the trends in career pathways of the 20 REs interviewed. Whilst limited in number, the trend in career pathways may illustrate the patterns of the impact of the EngD programme through the REs' career development. Furthermore, such career development implies the contribution of the programme to the broader range of 'highly-skilled' and 'industry ready' human capital. In order to illustrate the career pathways of the former REs they were asked to elaborate their career progression before and after the EngD programme.

Table 12: Career trends of former REs

Career path after graduate	Quantity	Proportion			
Change Company	5	25%	**Type**	**Quantity**	**Proportion**
Stay in the sponsoring company	15	75%	Fresh graduate	6	40%
			Experienced	9	60%

Table 12 shows that 15 out of 20 REs have been employed by their sponsoring companies upon the completion of the EngD. Nine out of the15 REs (60%) had had industrial experiences prior to joining the RE. This include those who had been employed in the company and sponsored to pursue by the employer, and those who had worked in industry, stopped working and pursued the EngD programme. Whether or not the experienced REs are more likely to be employed by their sponsoring firms after their EngD graduation needs to be examined further.

The other 5 REs who didn't stay with their EngD sponsoring firms have moved on with a variety of impacts and career pathways. For example, *RE Manufacture-Chemicals* states that her EngD project was extremely successful, with a technical outcome which led to a new product. She was offered a job upon the completion of the programme but decided not to stay and successfully shifted her career to a banking sector, currently with the highest range of income in the questionnaire used. She claims that the business knowledge and the transferable skills she has obtained from the EngD programme has helped her transit into the banking industry.

There are REs who moved between academia and industry. *RE Formulation-Consumer Goods* stated that that his project was a relatively short-term one and that his sponsoring firm had made it clear that they were not looking for an engineer upon the completion of the project. He took up a post-doctoral fellow post and then moved to an industry research position.

Table 13: Promotion trends of former REs

Promotion trend	**Quantity**	**Proportion**
Promoted to senior engineer	8	40%
Promoted to manager	8	40%
Other	4	20%

In terms of career progression, Table 13 illustrates the promotion trend of REs upon the completion of the EngD programme. 8 out of 20 REs (40%) continues to stay within technical roles, and have since been promoted into more senior roles within the technical fields. Another 8 REs (40%) has made a career change towards more managerial roles.

There have been cases of international career trajectories. For example, *RE Optics-Laser* was sponsored by his prior employer overseas as he was not eligible for the EPSRC funding. Upon completion of his EngD

programme he was promoted to the role of "Department Leader" in his sponsoring organisation. After 2 years he was then offered a professorship in the UK, sponsored by industry partners related to his technical area.

RE Manufacture-Energy with industry experiences, currently holding a managerial role with one of the largest oil and gas companies in the world, has made a significant career progression. He stayed at his sponsoring firm and within four years after his EngD graduation the company promoted him to larger management responsibility within the technical area. His salary doubled after completing the EngD programme. Currently, 8 years after completion of the programme, his salary level is within the highest range in the scale used in the questionnaire (see Case study).

Alumni case studies

Individual career pathways and impacts from the EngD are unique and diverse. In order to highlight some of these outcomes within the specific contexts, the following three case studies present the cases based on the interviews. The three cases present different and diverse career pathways – prior to the EngD, during the EngD and after the EngD– ***Case 1*** shows a female former RE who changed from chemistry industry to the banking sector after the completion of her EngD. ***Case 2*** shows a case of a former male RE who had had a number of industrial experiences, completed the EngD, with subsequent career progression and promotion and now based overseas. ***Case 3*** is an existing RE who is close to completion of his EngD. His case is very unique as his EngD is based on his own technology start-up company.

Box 1 Case studies of RE alumni

Case study 1

RE alumni (Chemistry, fresh graduate) had just completed her first degree and was looking for a job when the supervisor of her final year project introduced her to the EngD scheme. For her, the EngD stipend was an important element as she was interested in getting a job. "If it wasn't for the sponsorship there was no way I would have gone to do the EngD." Her EngD project was based at a chemical company where she developed a technique which was then adapted for hair analysis, leading to a new product. "When I left [the company] it was the largest product launch that year and had the potential to generate revenues of many millions." The outcome from the EngD project was leading to a new product, with potentially large financial benefits and she was offered a job at the sponsoring company. However, she declined the offer and decided to look for a job in a different sector – considering the completion of the EngD programme as an opening for her new career opportunities. *"Personally EngD gave me confidence to look into different industry – far reaching different job opportunities." ….tangible skills, project management experiences, maturity, overall exposure to business environment, finance management, operational management, working with different people, working on commercial goals; all useful to advance my career."*

She successfully entered a very competitive graduate scheme at an international bank and then experienced three locations within the bank - commodities, project management and risk management. Then she moved to a project management job – which she describes as "a similar type of project management" as she had experienced during the EngD programme. Then she moved to another bank as a project manager. Recently she has become a freelance, working on a management consultancy role, and is contracted by a major high-street bank.

The former RE commends the EngD programme and what it offered her – *"The EngD programme far exceeded the expectation. Looking back, it definitely helped develop my career….Management course is definitely the advantage of the EngD programme over PhD. Sponsorship is an advantage. Company*

aspect, commercial aspects, are definitely an advantage rather than pure academic focus." She is currently working towards the chartered status under the Chartered Institute of Management Accountants.

Case Study 2

RE alumni (Manufacturing, experienced) was already an experienced engineer when he entered the EngD programme, following the closure of his previous employer. He found the EngD opportunity through the job advertisement website (jobs.ac.uk), and applied as an opportunity for long-term career development. The EngD Centre and the sponsoring company (the UK based large electricity and gas company) had developed long-term research collaboration, where his EngD project was based.

The outcome of his EngD project resulted in the development of an innovative solution in the form of a safety harnesses used in engineering work. The solution was patented and a number of scientific papers and conference presentations were produced from the EngD project.

After finishing his EngD, the RE was offered a job and continued working for his sponsoring company where he lead the implementation of the developed technology solution to become a commercially available product in collaboration with leading manufacturing suppliers in the UK. In addition to working as a senior engineer, the RE has taken up management responsibilities.

After four years he left the company and moved overseas to take on a specialist engineering role with one of the largest international oil suppliers in the world. Currently he is leading a strategic project to enhance the reliability of the subsea cable network feeding critical offshore oil producing facilities.

About the EngD programme, which he highly commends: "*The well-constructed management program opened my mind to different parts of life. My career prospects have been transformed immensely by the Engineering Doctorate, due to the combined technical and professional development elements forming it. The good thing about that is I'm now able to use the skills in real life. ... It gave me an insight... I've not had to use (some of the courses) specifically after my Engineering Doctorate, but the combination of this expertise and the tools learnt will definitely help to advance my career prospects even further*."

He suggested that the EngD programme would be of interest to international companies like his and a great opportunity to develop talent pools in a global context.

Case Study 3

RE (Optics & Photonics, experienced) has over 10 years experience in electronics engineering and international R&D policy work. He started the EngD programme with an interest in 3D display technology and creating a high-tech start-up company. The RE founded the firm in 2008 and by appointing a technology entrepreneur on the board of the company, who acted as the industrial supervisor, the start-up company has been able to 'host' the EngD project. During his EngD, one patent was granted, some £300,000 raised and the company now has four employees. The holographic display technology has been featured on The Gadget Show TV programme and the innovation from the EngD research has been disseminated through various media, including a trade magazine, conferences and newspapers. He has also won numerous prizes, awards and grants to support his research. With regards to his skills development, the RE comments:

"the MBA component was excellent for starting up a company, especially the marketing, accounting and finance modules as I had to write business plans and pitch for funding to raise money from private investors."

Although having an EngD project based in the RE's own start-up company is a rare case across the EngD centres/IDCs, the RE argues that the EngD programmes should be more "entrepreneurial and risk taking" in their approach.

He recommends that the EngD programme should "*target more small and medium high-tech companies as they would add more value, given that SMEs create more jobs and can innovate faster*." Furthermore, he suggests that more mature people with industry experiences who want to make career change could use EngD by trying out new ideas, and there should be more supports for this.

2.4 Additional comments and recommendations from the interviews

2.4.1 Comments and recommendations from the alumni

EngD alumni's Perceptions of the EngD in comparison to the PhD

The question was asked to the alumni REs what makes them stand out as EngD graduates compared to PhD graduates. Many alumni see the advantages of the EngD over the PhD in terms of its industrial relevance. The nature of EngD project as having a broad portfolio and commitment and interests from industry were commented on by industry partners, which were repeated by the RE alumni.

> *One major strength with EngD is that you're able to tailor the details. With PhD you have to find one string and you have to keep following this one line of enquiry. In my case I was able to tailor and not have to be on one aspect. I could chop and change and that was strength in terms of breadth in research (RE Formulation-Consumer Goods fresh graduate)*

> *"from the very beginning you know that what you're doing is of interest to the industry and you know that they want you to give them results. You feel much pressure and you feel interests all the time. You know that they have that expectations and you know what they want to do with your work and how it's applied. …The fact that in EngD there is an industrial interest right from the start gives you an advantage. (RE Manufacture-Aerospace 3, fresh graduate)*

> *"I think EngD is much better than PhD purely for the experience you get in the industry, including the courses you get. ….I don't think other programmes give engineers the knowledge about management. When you talk to the management they care more about the business side. I think EngD makes it more rounded-engineering, due to the business courses. If I had to choose between EngD and PhD I will choose EngD every time." (RE Manufacture-Aerospace, experienced)*

RE alumni's recommendations in relation to the EngD programmes

Branding and awareness-raising

The issues of branding involves the following

1) Awareness-raising with industry,
2) Awareness-raising with academics

3) Awareness and expectation management of the prospective REs
4) Improved communication between alumni and the centres for branding

With regards to branding and awareness-raising, about half of the alumni interviewees commented that it is something that the EngD scheme needs to improve:

> *"We should promote EngD as a brand, because it's not done."*

> *"I think it's an amazing programme and that more people should know about it. If the UK wants to get serious about it, it's an amazing way to bridge science and basic research to industry; it fills a gap that the UK has been historically weak at in terms of applying ideas and basic research in industry."*

> *"Not many people know about the EngD program, especially not many organisations know about it or sponsor it. There are companies who might be interested if they know more about the program."*

There are some companies that have funded a number of EngDs with much higher awareness, and big companies tend to be more aware of the scheme and resources to run it as part of the wider university collaboration.

The following comment from one former RE may need to be considered in terms of different types of companies.

> *"I think the EngD program deserves better backing. …the financial climate in the UK in recent years make companies feel reluctant to invest vastly in universities, which indicates that either EPSRC need to invest more or they need to find another way to strengthen the funding"*

One of the former REs pointed out the confusion caused by the names of the scheme – EngD and IDCs/CDTs:

> *People tend to invent names or change different names to the clean EngD. Having lots of different names make people confused.*

It is recognised that critical mass and senior leadership of the EngD alumni is required, which would take a long time.

> *"More EngDs are needed who will influence companies and decision-making – Until then EngD need to present real hard evidence of what they can change and how much improvement they can make (e.g. how much money would company save)"*

> *"I think it takes time. For example, someone I know who did EngD at the first cohorts is now finally taking senior positions. There's not enough people to make penetration at senior level positions in a number of industries. Building the brand will happen organically once more and more people fill up the senior positions. In terms of the programme itself, it also goes case by case. It depends highly on the individual, as well as the scope of the problems... there are many variables involved."*

In general, the role of alumni in raising awareness by linking more with the centres is pointed out.

"The communication between the EngD alumni and the EngD centres should be better"

Two of the recent RE alumni that were interviewed are working as an interface with the universities, or more specifically with the EngDs.

> *Yes I now manage the EngD program at [the company], so I do have management responsibilities for the REs now. I also stayed in contact with the REs during my year and a number of them were recruited by [the company] and are still working now.*

The **awareness of industry** about the nature of the EngD and the responsibility of the sponsoring firms is also important.

> *Some companies can see it as cheap labour and using the EngD students as someone already working for the company. I emphasised that EngD students must focus on the novelty of the work and the practical research they're involved in and not get involved with the daily staff at the company, mainly because I think that it's a risk to the programme.*

Difficulties in recruiting experienced engineers

One of the alumni interviewees pointed out that "the biggest challenge is quality of candidates available."

> *"They need the right supervisor to select the right candidates. EngD is more valuable than PhD for the future organisational developments."*

Another former RE stated the needs of more industry experienced REs:

> *"a lot of EngD students came out straight from MSc and they're lacking in industrial relations techniques, working with other people, holding meetings etc. So I think some of the students would benefit more if they work in the industry a couple of years before going into EngD."*

Two of the former REs, who had been working in industry prior to the EngD programme, mentioned the financial challenges of being REs after working full time in industry. Whilst both of them appreciated the stipend from the EPSRC, and top-up from their sponsoring firms, and the fact that they were not taxed, one of them said the financial position was getting difficult towards the end of his programme as the general increase in the cost of living had not been reflected in the stipend.

Another RE alumnus with prior industry experience said motivating future engineers and putting incentives in place to attract people with experience would be a solution:

> *"I think this program is really good value to the industry and the EPSRC. Is it good value to the individuals; well, my personal view is that if the UK is serious about investing to develop good engineers for the future then they should pay higher wages to encourage people to come into the EngD program, because if they don't they are not going to attract people to do it. I think there should be serious thoughts, such as talking to the people on the ground, in terms of the package that is given to the engineers. There needs to be a search for people with experience, people with ambitions – but these people would need to be motivated because it will be a big step for them to give up their salaries. I think it would show the value in place of the program by the government."*

2.4.2 Comments and recommendations from the industry partners

Comparison with other industry-university collaborative mechanisms

For industry partners, there are a number of choices in terms of the mechanisms to collaborate with academia. For example, there are choices between having doctoral students and post-doctoral researchers in terms of time-scale to get results and also costing.

A manufacturing firm respondent said that it is too expensive to have a post-doctoral in the UK research system, whilst having a doctorate is time-consuming but effective in terms of finance. Another respondent [Consumer Goods] said that having doctoral students may involve a higher risk and takes a longer time-scale, whereas funding a post-doctoral may result in quicker outcomes.

The diversity of the doctoral programmes and different types and nature of collaborative research and knowledge production are appreciated by the industry sponsors. It seems to be a common view among the industry respondents that the EngD is unique and "has its own place" as a mechanism for collaborative knowledge production through doctoral students.

A comment was made by the nuclear sector that from an industry perspective it is important to have a "balanced portfolio of R&D activities and skills." It is argued that different centre types – CDT and IDC - complement the R&D programme across the sector, covering different scope of technology and different types of skills needed for the future leadership and technical research in the sector.

Specific interview quotes illustrate the variety of views from industry sponsors:

Two of the manufacturing respondents stressed that, if they were to choose, they prefer the EngD to the PhD.

> *"between the two [PhD and EngD], the EngD is better because it allows for a portfolio of research rather than a single monopolistic (research), and because of the continuous involvement of the operating/sponsoring company, it means that you start seeing research pulling through in the short-term rather than a PhD…..the research happens in the company much more quickly and incrementally, rather than being left to the end of 3 years and then extract something useful or ignore the research. It's not immediate, but it's incremental and it has more chance of getting attracted in the work place." (Manufacturing 2)*

> *"Given the choice, between PhD and EngD, if I am interviewing I would go for EngD because of the breadth of their expertise. I prefer engineering doctorates for several reasons. Unlike the PhDs, the EngDs don't have to do a very deep isolated project. The EngD can do up to five related projects. They are more suitable to industry as you have different clients and different needs to solve" (Manufacturing 3)*

There are similar collaborative doctorate schemes running in the UK, such as Industry CASE PhD and PhD combined with KTP. One interviewee explained his view as follows:

> *I think in terms of the value of money, the IDCs provide much better value than the CASE PhDs. The EngD is a more structural involvement from the industry side. We are working closely with the university and have a much bigger driving impact. The EngD gave us the direct involvement and the benefit in it. The CDTs, in general, 5 years with 50 PhDs in a specific topic could be too narrow. (Public research organisation)*

Industry sponsors tend to highly appreciate the embedded nature of EngDs/IDC schemes in terms of industry relevant research and recruitment opportunities and a potential for future human resources.

We have some PhD students … even though they have industrial supervisors, the industrial supervisors have very little impact in terms of influencing the projects because the students reside more within the academic setting.. It's much easier to influence EngD type projects.

These two have different levels of embeddedness within the firm (Nuclear membership organisation).

One of the industry partners emphasised the importance of the balance between the blue sky research and more applied research, which needs to be covered by both PhD and EngD.

"Distinctive advantage of EngD is the fact that it is applied in nature. However, this is one model – the spectrum of models – both PhD and EngD are needed. The EngD allows much closer interactions, closer support system than the PhD" (Energy 1)

Recommendations from the industry partners to the EPSRC, the AEngD and the university sector
The following comments were provided from the industry partners in response to the question about the "recommendation about the EngD, to the EPSRC, the AEngD and the University sector":

Awareness-raising and evidence-base

EngD should be promoted more actively. Still lots of people don't know what EngD is. It needs more proof. Academics don't know what it is. Academics want PhDs, and students go away [unlike the EngD] (Manufacture 1)

The awareness level of the EngD could be raised as a whole. (Nuclear membership)

Relevance of training courses

"It is important that the universities provide relevant courses e.g. finance, project management, in order to make engineering graduates broader" (Manufacture 3)

Continuing support
Five industry interviewees stressed the importance of the continuation of the EngD programme, as distinguished from other PhD programmes.

My view is, and I am sure many industrial contributors agree, that you have a huge funding ground for doctoral training and it's very much up to the universities as to what style of doctoral delivery they offer. What I want EPSRC to do is strongly prioritize for the IDCs that offer EngD provisions, or EngD style position, rather than PhD. (Manufacture 2)

I think we have 55 CDTs with 19 of those IDCs [sic] I think there should be more IDCs. (Public research organisation)

I think the EPSRC needs to continue to support this programme. (Nuclear membership organisation)

To EPSRC - "We need more schemes like this" (Manufacture 3)

Being in this country, the challenge is to find the right funding opportunities and to find universities that have the expertise. ….we find them within the continent rather than the UK (Consumer Goods)

Better branding and USP of the scheme

Several industry respondents pointed out the importance of awareness-raising. This includes communication with broader industry on how the industry gets involved in the EngD programme and what opportunities entail. Another point is raised about the importance of the better branding on what differentiates the EngD from other collaborative doctorates programmes.

In other words, the unique selling point of the EngD has to be communicated more – *"it does help bring people more closely aligned to industry needs"* [Energy 2].

As another interviewee put it:

> *I think there are still lots of more work needed to raise awareness on what the opportunities are for EngD. I also think we can work with other people in the industry as a block to make sure that we get the most out of our collective intelligence. I think a significant improvement that we can bring to EngD is by saying that the EngD is so much better, in order to make the scheme much more profound and important. [Retail]*

Those who participated in telephone interviews are the industry sponsors that have participated in several EngD projects with close engagement with the programme. Therefore, they have a good understanding of the nature of the programme. Those companies with limited experiences may not share such a view, and might find it difficult to understand the mechanisms and benefit from the outcomes as much as those repeated sponsors have done.

Understanding the variety of the industry needs

One of the industry interviewees who started-up a venture firm based on a technology resulting from the EngD project (based at a large technology organisation) mentioned that whilst he highly appreciated the nature of the EngD programme with commercially relevant training, it has been difficult for the small start-up company to engage with the four year collaboration with academia through EngD. As an alternative, he used a PhD project, which was entirely owned by a university, as a less risky way of collaborating with academia in order to develop a specific technology of their interest. He is now thinking of a possibility of developing a new EngD project, as his company has been acquired by a large organisation and it is the right time to build up a new technology area.

2.5 Interview questionnaires

Industrial perspective

Thank you very much for kindly agreeing to participate in this study.

The questions below are prepared as a guideline for the telephone interview.

Your answers and comments are treated anonymously and with strict confidentiality.

Your industry_____

Your organisation _____

Your role _____

1. In what capacity have you engaged with the EngD programme? - **Has your company sponsored or have you supervised EngD projects?** - **If so, how many sponsoring/supervising?**
2. From your experiences, how are the projects defined and who plays a key role in defining the EngD project?
3. Which unit/department within the company is in charge of the EngD collaboration? ☐ **Human resource department** ☐ **Unit managers** ☐ **Research directors** ☐ **The senior management team** ☐ **Other**
4. Is there anything particular your company or the sector looks to gain from the EngD programmes/projects in particular?
5. What kind of individuals is the sector looking for as future employees? Does the EngD programme reflect such needs? What are the criteria for selection process for the research engineers (REs)?
6. When you are selecting REs, do you bear in mind that they could be potential employees for your company?
7. What positive outcomes are you looking for in terms of a successful EngD collaboration? (Please indicate according to the importance : 1= Most Important, 3= Least Important) **How much has the outcome of the programs so far met your expectations? Please give some examples.** ☐ **Future employees** ☐ **Future managers and leaders in the sector** ☐ **New technologies** ☐ **New product and new markets** ☐ **Cost savings** ☐ **State of the art research expertise** ☐ **Maintaining networks** ☐ **Developing/testing a new method of innovation** ☐ **Continued collaboration with academia** ☐ **Other (please specify)**
8. Is there any different strategy between recruiting stipend REs and sending existing employees for the EngD? (e.g. knowledge exchange with academia, opening new markets, changes in

business operations)? **- Do many firms send existing employees for the EngD programme?** **- How often does the sponsoring firm employ the stipend REs after the completion of the EngD?**
9. How do you track outcomes and impacts as a result of EngD program/projects? **Do you have any 'evidence' of the EngD impacts?** **Could you describe an/some interesting case(s) from your collaboration with the EngD programme?** **Is there any significant outcome or impact from the project/programme that you are aware of?**
10. Please specify tangible or intangible benefits from the EngD program, such as: **☐ Changes in business processes** **☐ Opportunities in new business areas** **☐ Changes in materials used in the manufacturing** **☐ New processes and services** **☐ Solving problems in the sector** **☐ IPs** **☐ Human resources and skills** **☐ Other (Please specify)**
11. Have there been any long-term strategic changes in your organization (or other organisations you are aware of) as a result of the EngD programme? **☐ Changes in codes of practice** **☐ Changes in supply management** **☐ Changes in policy** **☐ Other (Please specify)**
12. How would you compare the outcomes of EngD programmes to those of PhD programmes of similar nature?
13. In your opinion and from your experiences, what are the benefits and constraints of industry-university collaboration? Are you seeking for long, medium or short term benefits? In what ways does the EngD programme fit within the broader collaborative relationships with academia? Please give some examples.
14. Is there anything you wanted to do differently? Could you make a recommendation on how the program could improve?

Thank you very much for your time and kind co-operation.

Additional information

- Please let me know if you are interested in receiving the results of this study.

- Would you recommend anyone whom we might approach for interviewing for this project?

This study is supported by the AEngD and EPSRC. It has been developed in collaboration with the AEngD Sub-group on the EngD Impact study, and is being conducted with a group of MBS MSc students between June and September 2013.

The telephone interview will be tape-recorded unless otherwise agreed. The information gained through the interview will be used for the purpose of the study/project only, and will be treated anonymously, with strict confidentiality. For any queries, please contact Dr. Fumi Kitagawa (Manchester Business School, University of Manchester) Fumi.kitagawa@mbs.ac.uk 17 June 2013

Research Engineers ALUMNI

Thank you very much for kindly agreeing to participate in this study.

The questions below are prepared as a guideline for the telephone interview. Your answers and comments are treated anonymously and with strict confidentiality. If you could kindly fill in some of the answers (e.g. Q3 - Project Title, Dates, Company etc), and send back, that would be very appreciated.

1. Please tell us about your industry experience before entering the EngD programme. How many years? In similar industries to your EngD project?

2. Could you briefly describe your sponsoring company (size, the characteristic of the organization) and the unit where you work?

3. Please tell us the background of your EngD project. How was the project initiated/defined?

1. Project Title:
2. Date Started:
3. Date Finished:
4. Academic Supervisor:
5. Company (Sponsor):
6. Industry Supervisor:
7. Company Size (Under 10 Under 50 Under 250 Under 1,000 Over 1,000) ; (University spinout Y/N)

4. What were your motivations/expectations for entering the EngD program? (Please indicate 1-3 with 1 being "Most Important" and 3 being "Least Important".)

- ☐ Stipend/Studentship
- ☐ Opportunity of collaboration with the industry
- ☐ Specific interest in the research area
- ☐ Conducting research whilst working
- ☐ Interest in the sponsoring company
- ☐ Management courses offered on the program
- ☐ Career prospects after graduation
- ☐ Other: _____

Additional questions:

Why did you choose the program at the university you were enrolled in?

Was EngD your first choice for your doctoral program?

What do you think were the reasons you were chosen as RE?

5. **How much has the outcome of the EngD program met your expectations and why?**

6. **What is your current position within your company? Could you explain a little bit about your career path after the completion of your EngD? To what extent has your career option been influenced by the EngD programme e.g. academic/industry supervisors?**

7. **What is your current range of salaries?**

- ☐ Under £34,000
- ☐ Between £34,000 and £42,000
- ☐ Between £42,000 and £48,000
- ☐ Between £48,000 and £56,000
- ☐ Between £56,000 and £66,000
- ☐ Over £66,000
- ☐ Do not want to answer

8. **Do you still carry on research after graduating from the EngD? If "Yes", is the area of research related to your EngD research?**

9. **In what ways do you think your EngD research benefited your sponsoring company or the industry/society in more general? Was there any explicit strategy at the corporate level/project level or at the EngD Centre?**
   - **How would you know the impact of your project in the short term as well as long term?**
   - **What do you think the 'impact' of your EngD project are, for example, the technology or research outcomes as part of your EngD?**
   - **Has the technology been patented, or has it led to other significant innovation or organizational changes either to the firm or the industry?**

10. **Which Skills did you find most useful when you were on the EngD programme, and which skills have you found most useful in your current employment?**

Before EngD	*After Job*	
☐	☐	**General Skills** (Example: leadership skills, communication skills, team-work skills etc.)
☐	☐	**Business-Oriented Skills** (Example: finance, management, marketing, start-up)
☐	☐	**Industry specific knowledge and Technical knowledge/skills**

11. **What is your perception of the most valuable knowledge/skills that you gained and that the company gained from you or your work during the EngD and afterward?**

12. **Have the business skills that you gained through the EngD programme helped you in your transition into your current role within the industry?**

Do you think your skills and knowledge are specific to the firm that you have worked

with?
13. Do you think that the EngD qualification has helped you advance into better positions within the industry?
14. Are you still in contact with your previous academic/industry supervisors, peer REs, and the EngD centre? Do you engage with the EngD alumni? If "Yes", could you please explain what the benefits of networking with the various parties of the EngD program are?
15. Have you supervised or do you intend to supervise new EngD students? Do you recommend EngD programme, and why?
16. Do you think the EngD degree and experiences give you competitive advantage in the labor market? - **Have you had any promotion in terms of job roles or salaries after the EngD programme?** - **What are your strengths gained from the EngD programme?** - **What made you stand out compared to other doctorate students (e.g. Traditional PhD, CASE PhD, etc.)?** - **In general, do you believe that EngD holds more value in comparison to PhD? Why?**

Thank you very much for your time and kind co-operation.

Additional information

- Please let me know if you are interested in receiving the results of this study.
- Would you recommend anyone whom we might approach for interviewing for this project?

This study is supported by the AEngD and EPSRC. It has been developed in collaboration with the AEngD Sub-group on the EngD Impact study, and is being conducted with a group of MBS MSc students between June and September 2013.

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For any queries, please contact

Dr. Fumi Kitagawa (Manchester Business School, University of Manchester)
Fumi.kitagawa@mbs.ac.uk 19 June 2013

3. HESA Destinations of the Leavers of Higher Education Survey

The data on destinations and career development of the EngD graduates have not been systematically collected and analysed. As a quantitative background to the main qualitative evidence provided in this study, the initial analysis of the HESA Destinations of Leavers of Higher Education (DLHE) Survey data was conducted in order to understand the destinations of the EngD alumni. The DLHE survey asks leavers from higher education what they are doing six months after graduation.

HESA DLHE data and analysis

The data on EngD graduates was initially obtained from the EPSRC, which was matched and integrated into the HESA DLHE data. Data on three cohorts of students (2008/09-2010/11 academic years combined) was matched and made available for this study. An equivalent set of data on Industrial CASE graduates funded by the EPSRC was also made available. There are 125 EngD graduates across the three cohorts and 201 Industrial CASE graduates for the same period.

Where appropriate, the HESA DLHE data on overall PhD graduates across all disciplines (total number 20,795; 2008/09-2010/11 academic years combined) is stated. In addition, where possible, the DLHE data was sorted by "Principal subject" and 14,453 graduates' data with the "Principal subjects" A-K [2] was extracted, which broadly correspond with the subjects of doctoral students funded by the EPSRC EngD and Industrial CASE schemes.

Contexts of the two doctoral programmes

The main purpose of the analysis is not to compare these different types of doctoral programmes, but to illustrate various contexts of impacts related to the doctoral programmes with varying forms of industry collaboration.

The Industrial CASE scheme provides funding for "industrially relevant PhD studentships that are jointly supervised by the academic and industrial partners" where "businesses take the lead in arranging projects with an academic partner of their choice" (EPSRC, 2013b). The Industry CASE students need to spend at least 3 months of their 3.5 year project working in a non-academic setting with the collaborating organisation. The time spent within industry is significantly shorter than that of the EngD. EngD students spend up to 75% of their time in industry (about 3 years). EngD programmes are based in distinctive centres (EngD Centres/IDCs) and have more taught elements in the area of business administration. Industrial CASE students are located in academic departments.

Subject area

In terms of the principal subject area, the EngD graduates have high engineering related areas. For the Industrial CASE graduates chemistry is the largest, followed by engineering related subjects.

[2] See, HESA JACS Principal subjects: A Medicine and dentistry; B Subjects allied to medicine; C Biological sciences; D Agriculture and related subjects; F Physical sciences; G Mathematical sciences and informatics; H,J Engineering and technology; K Architecture.

Table 14: Principal subjects of their studies -the EngD and Industrial CASE PhD graduates (2008/9-2010/11) (Source: HESA, DLHE)

a/ Principal subjects of the EngD graduates

General engineering	16%
Chemical, process & energy engineering	14%
Materials technology not otherwise specified	12%
Electronic & electrical engineering	11%
Mechanical engineering	10%
Civil engineering	8%

b/ Principal subjects of the Industrial CASE PhD graduates

Chemistry	29%
Civil engineering	13%
Electronic & electrical engineering	8%
Physics	8%
Computer Science	6%
Aerospace engineering	6%

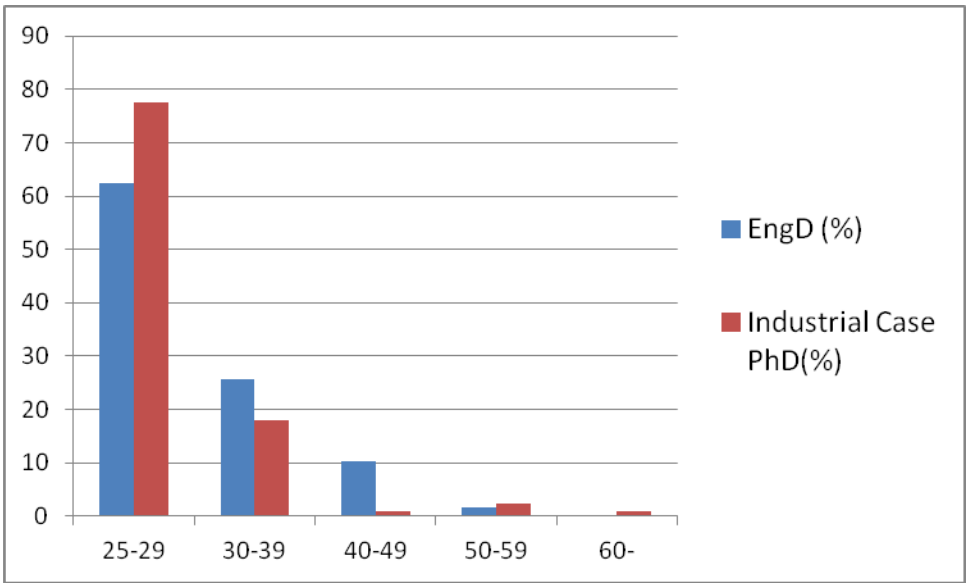
EngD graduates profiles and demography

In terms of demography, the EngD graduates are relatively older than Industrial CASE graduates. 37.6% of the EngD graduates are over 30 years old whilst the equivalent number of Industrial CASE graduates is 22.2%. 12% of EngD graduates are in their 40s and over, the equivalent is 4.4% for Industrial CASE (Table 15).

Table 15: Age distribution of the EngD, Industrial CASE and Other PhD graduates (all disciplines) (2008/9-2010/11) (Source: HESA, DLHE)

Age group	EngD (%)	Industrial Case PhD (%)	Other PhD (%)
21-24	-	-	1.9
25-29	62.4	77.6	46.1
30-39	25.6	17.9	33.8
40-49	10.4	0.99	10.6
50-59	1.6	2.4	6.4
60-	-	0.99	2.9

Figure 3: Age profile of EngD and PhD graduates



Female EngD graduates constitute 17% of the whole EngD graduates; 23% of Industrial CASE graduates are female. A small number of students comes from European countries for both EngD (5%) and Industrial CASE PhD (7%) whilst there is no information available in the DLHE for those not sponsored by the EPSRC who come from outside the EU countries.

There are a small number of REs from non UK/EU countries who are not funded by the EPSRC grant. The profiles of those non-UK/EU (and non-EPSRC funded) REs need to be further studied across the IDCs.

Destinations and employment status

Six months after the completion of the programmes, 91.2% of EngD graduates are in Full-time paid work (including self-employed). This compares favourably to Industrial CASE graduates (79.6%), Other PhD (all disciplines) (73.9%) and Other PhD (principal subjects A-K) (78.8%).

In terms of how the graduates found their employment, 24% of the EngD graduates found a job as they "already worked" there (i.e. the sponsoring firm), higher than Industrial CASE graduates (10%) and Other PhD (all disciplines) (16%).

Table 16: How found employment - the EngD, Industrial CASE and Other PhD graduates (all disciplines) (2008/9-2010/11) (Source: HESA, DLHE)

	EngD	CASE	Other PhD
Own institution's Careers Service	6%	7%	3%
Newspaper/magazine advertisement	2%	2%	4%
Employer's web site	10%	13%	13%
Recruitment agency/website	9%	12%	9%
Personal contacts, including family and friends, networking	21%	22%	18%
Speculative application	-	4%	2%
Don't remember	1%	1%	2%
Other	10%	4%	8%
Already worked there	24%	10%	16%
Question not answered (default)	14%	10%	12%
Not applicable	5%	13%	12%
	100%	100%	100%

85% of the EngD graduates work in non-Education sector - 32% of EngD graduates work in Manufacturing, 27 % in Professional, scientific and technical activities. 15% work in Education sector.

34% of Industrial CASE graduates work in Education, followed by Professional, scientific and technical activities, Manufacturing, Information and Communication.

Table 17: Destinations of the Leavers by Standard Industrial Classification codes: the EngD and Industrial CASE PhD graduates (2008/9-2010/11) (Source: HESA, DLHE)

a/ Destinations of the EngD graduates, by Standard Industrial Classification codes:

Manufacturing sector	32%
Professional, scientific and technical activities	27%
Education	15%
Electricity, gas, steam and air conditioning supply	5%
Construction	5%
Public administration and defence; compulsory social security	2%
Information and Communication	2%

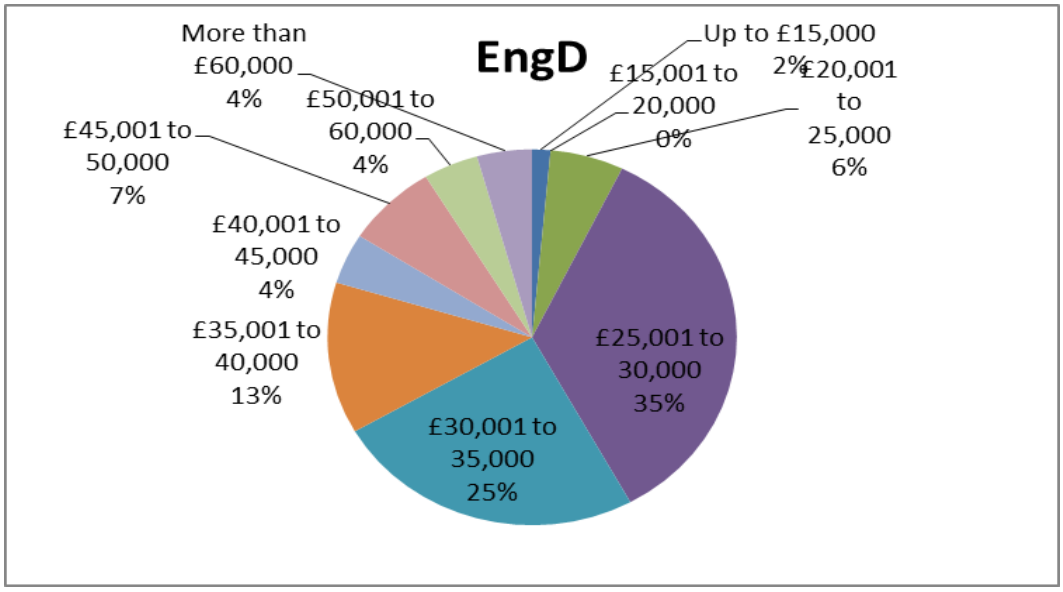
b/ Destinations of the Industrial Case PhD students, by Standard Industrial Classification codes:

Education	34%
Professional, scientific and technical activities	19%
Manufacturing	14%
Information and Communication	7%
Public administration and defence; compulsory social security	3%

Salary

Salary data in the DLHE is limited in terms of the size of the samples available. It is difficult to draw a general conclusion from the data presented here and careful interpretation is required when using the information. For those who are in full-time employment, 33.3% of the EngD graduates earn more than £35K per year. This compares favourably to Industrial CASE graduates (12.6%), Other PhD graduates (all disciplines) (29.8%) and Other PhD graduates (principal subjects A-K) (26.0%).

Figure 4: The annual income of EngD graduates in full time employment 6 months after the completion of their studies (2008/09-2010/11) (Source: HESA, DLHE)

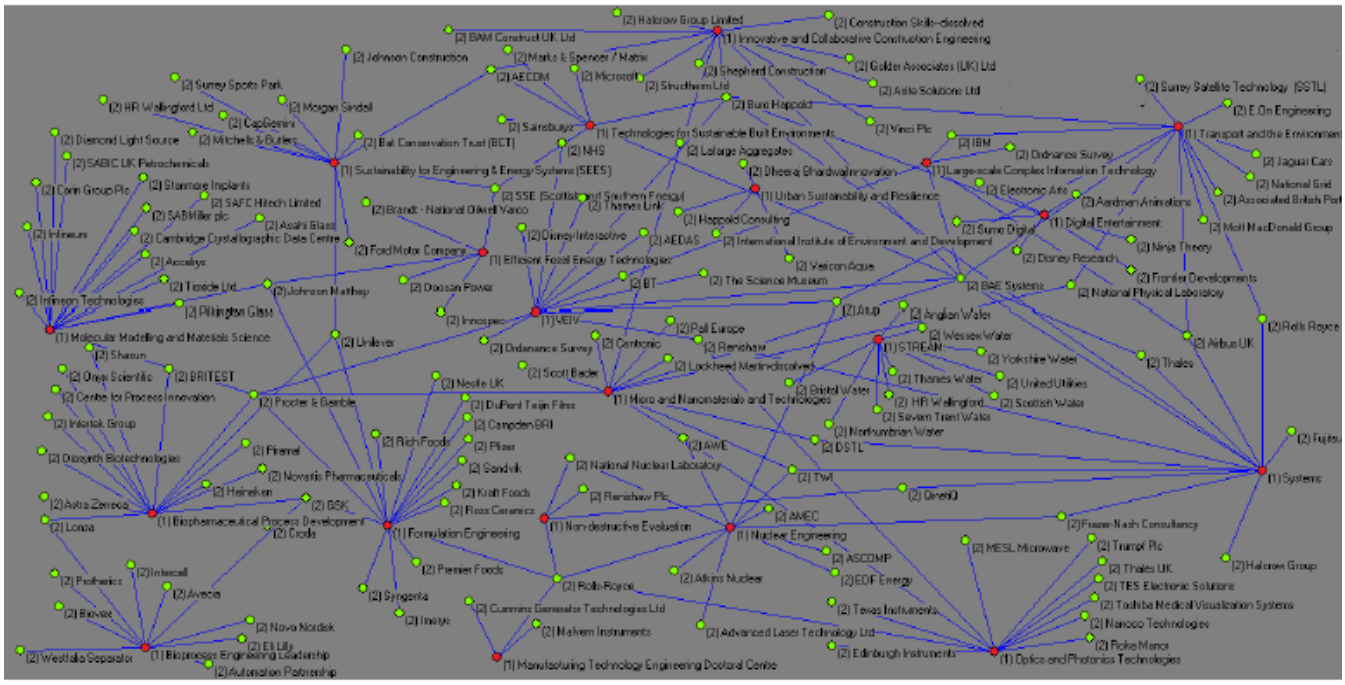


4. Exploratory snapshots of the IDC-industry partners linkages- network visualisation of the 2009 IDCs' industry sponsors

As an exploratory research method, the research team employed network visualisation software (Pajek) to demonstrate the linkages between the 2009 IDCs (including additional manufacturing IDCs set up in 2009) and their key industrial sponsors. Industry sponsors were identified using the information on the IDC websites and the lists available for each of the IDCs available on the AEngD website, and a data-base of the IDC sponsoring firms was created. The data-base of the sponsoring firms needs further development and refinement, and the network visualisation software has certain limitations.

Figure 4 is a preliminary visualisation of the network patters between the IDCs and the identified industry partners. The IDCs are shown in red, and industry partners are presented in green. There are several industry sponsors acting as nodal points, linking different IDCs (e.g. Rolls Royce, Thales, TWI, Buro Happold, National Physical Laboratory, BAE Systems, Airbus, Johnson Matthey). Some IDCs have broad inter-sectoral linkages whilst others are one-sector specific IDCs.

Figure 5: Network patterns between the 2009 IDCs and industry sponsors



Social network analysis would need to be further developed to illustrate the collaborative patterns the IDCs and their industry partners by combining with other analytical strategies, such as co-authorship analysis, biographic coupling and co-patenting analysis (see Youtie et al 2013).

5. Collaborative doctoral programmes – international perspectives

The EngD scheme provides a format of R&D and skills training which meets the needs of multinational companies both in the UK and internationally. It is therefore appropriate to review the UK programmes alongside the similar programmes across Europe and beyond. This would be an important area for future investigation.

The EngD scheme needs to be located in a wider institutional landscape of publicly funded collaborative doctoral programmes. In the study conducted by EUA (Borrell-Damian, 2009, p. 27),[3] the collaborative doctoral programmes are identified as follows:

> "*the doctoral theses carried out with interaction between a university, a company and a doctoral candidate. A distinctive characteristic is that industry experts take part in the supervisory committee, officially or informally. Industry can play several roles, but being in the supervisory committee is what effectively reflects the specific nature of the collaborative doctoral project.* "

Collaborative doctoral programmes serve as part of the university-industry interface in a variety of ways. Different contexts of collaborations need to be distinguished, including mechanisms of funding and the time required to spend within industry. Collaborative doctoral programmes are sometimes funded solely by industry/employer (e.g. industry sponsored internships/ fellowships), whilst there are different types of publicly supported collaborative doctoral programmes between university and industry, partly supported by employers/industry. In some cases, the students spend substantial part of the programmes within industry. In other cases, the collaboration does not require the doctoral student to spend period of time physically in the industry/employer. Recent international works highlight the need for "better data on, and more systematic tracking of" career pathways of all types of doctorates (Borrell-Damian et al., 2010).

In North America and Australia, like the EngD Centres and IDCs in the UK, the collaborative doctoral programmes have taken the forms of "research centres". The US National Science Foundation (NSF) has funded a number of university-industry cooperative research programmes, including the Engineering Research Centres (ERC) and the recent Industry-University Cooperative Research Centres (I/UCRC) (see Boardman et al., 2013 for the overview of I/UCRCs).

Efforts have been made to make the impacts of these Centres explicit. The US National Science Foundation Compendium on "Industry-Nominated Technology Breakthroughs of NSF Industry/University Cooperative Research Centers" provides an exemplar of visual presentations of impacts from the collaborative research centres. In the 2012 edition compendium, for the first time, statements of economic impact were added (NSF, 2012).[4]

In Australia, the Cooperative Research Centre (CRC) program has been running since the 1990s focusing on the production of "industry-ready" research graduates, and a series of impact studies have been conducted (Harman, 2004; Manathunga et al., 2012). In a recent study, CRC graduates approximately 5-12

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[3] Collaborative Doctoral Education: University-Industry Partnerships for Enhancing Knowledge Exchange, DOC Careers Project, http://www.eua.be/fileadmin/user_upload/files/publications/doc-careers.pdf [last accessed 14 October 2013]

[4] See the 2012 Compendium: http://www.nsf.gov/eng/iip/iucrc/docs/2012NSF_IUCRC_Compen-27Nov2012.pdf; See also, http://www.ncsu.edu/iucrc/PDFs/IUCRC_EconImpactFeasibilityReport_FinalFinal.pdf [last accessed 15 October 2013]

years post-graduation were targeted, along with a sample of PhD graduates from the same timeframe and matched disciplines from three research-intensive universities in Australian cities.[5]

In Europe, under the competitiveness agenda, the European Commission has been promoting the commercialisation of research by bringing public science and businesses closer. The model of "Industry-Led Competence Centres" (ILCC) has been promoted by the European Commission. The examples of ILCC include the ERCs in the US, CRCs in Australia, and Networks of Centres of Excellence in Canada, and these models are seen as policy instruments that can be deployed among the Member States (CREST Working Group, 2008).[6] One of the common features of ILCC is identified as having post graduate research students (e.g. PhD students) who work with industry and solve "interdisciplinary problems". The example of such centres in Europe includes Competence Centres in Sweden and KKK Centres in Hungary, amongst others. Whilst these centres have research students, the level of the emphasis on the research training activities as part of the centre function seems to vary.

In Europe, there are other collaborative doctoral programmes which seem to support individual doctoral students within the existing academic units, rather than taking the forms of autonomous "research centres".

- In Denmark, the *Industrial PhD* programme has been running over 40 years, conducted jointly by a private company, an Industrial PhD student, and a university (The Danish Agency for Science, Technology and Innovation, 2013).[7]
- The new "European Industry PhD scheme", recently created and funded under the European Commission, seems to have modelled on some of the Danish experiences.[8]
- In France, *Industrial Agreements for Training Through Research* (CIFRE) is a programme to develop "public-private research partnerships based on these jointly financed by firms and the National Association for Research and Technology (ANRT)". One of the evaluation studies states that 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".[9]

Specifically with regards to the manufacturing research area, a recent review on *International approaches to manufacturing research* (O'Sullivan, 2011) assesses EngD/IDCs from an international perspective:

> "*many of the goals and characteristics of the EPSRC EngD and industrial doctorate centres programme are supported by international experiences and by practices highlighted by international manufacturing research leaders*."

There is a dearth of empirical evidence. Understanding the impact of EngD in an international landscape and drawing lessons from comparative perspectives would be important for a future study. Lessons could be drawn from comparative studies across different sectors and across different programme types.

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5 Manathunga, C., Pitt, R., Cox, L., Boreham, P., Mellick, G. and Lant, P. (2012) Evaluating industry-based doctoral research programs: perspectives and outcomes of Australian Cooperative Research Centre graduates, *Studies in Higher Education*, 37(7), pp. 843–858.

6 See http://ec.europa.eu/invest-in-research/pdf/download_en/illc.pdf [last accessed 14 October 2013]

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