Theme: A questionnaire-based survey supporting a project to understand the potential impact of an academic Doctorial Training Centre on catalyzing academic-industrial collaborations within its technology sectors

Title: Enriching domain knowledge of the academic-industrial landscape of an Engineering Doctorate Centre: a multiple-sector industrial R&D survey

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Abstract This paper outlines a survey of industrial-academic R&D activities among over 650 technology enterprises in the UK. The project was driven by the EPSRC Engineering Doctorate (EngD) Centre in Virtual Environments, Imaging and Visualisation (VEIV), a collaborative centre of excellence based at University College London's Department of Computer Science. Over 70 doctoral students have entered the standard EngD programme, most being co-funded by an industry partner, which constitute a diverse portfolio of technology enterprises, non-profit bodies and engineering services.

The EngD is devised to address a clear need to well-trained engineers in these technologies, including in construction and building management (CITB, 2012; UKCES, 2012), graphics for creative and other applications (NESTA 2010, 2013), and the creative economy generally (BIS 2010, 2011). Hence, VEIV's research remit is led by industrial, commercial and policy requirements. In recent years, we have found that our EngD projects have moved beyond the core topics of 'VEIV', as they were initially proposed, which has prompted the requirement to enrich our

2

understanding of R&D activities across this broader range of themes. The researchers have addresses this requirement with a UK-wide survey of R&D activities in imaging, graphics, vision, interaction, engineering services and advances in built environment design.

The R&D audit comprises a formal knowledge component of the EngD Centre, enabling the management committee to support those working in industrial R&D and research policy, as well as to graduates of the EngD programme. This capability is a significant advance on the Centre's role as a catalyst in its knowledge landscape. The ultimate objective is to produce a rich dataset of R&D activities, from which we can produce sector-specific reports, and so map our broader 'knowledge landscape'.

The preliminary stage of the study involved the building of a comprehensive database of all companies of any size active in R&D in the relevant technology sectors (including details of the most appropriate point of contact in these companies, such as academic liaison office, director of research, chief technology officer, or other). This stage proved productive in that it revealed a greater range of technology enterprise sectors than had been previously considered.

Introduction

The Engineering Doctorate Centre in Virtual Environments, Imaging and Visualisation is University College London's leading centre for science and engineering research in the field. EngD projects have led to technology advances in several areas, including body scanning, medical imaging, 3D fabrication, and

generative design. A range of other projects have enhanced graphics and interactions in healthcare, urban planning, robotics and communications.

The EngD VEIV funds and supports research engineers (REs) studying in areas related to the use of visualisation and imaging in engineering and design. An EngD is a doctoral degree, including intensive taught components, funded in combination between EPSRC and a unique industrial partner. The EngD is typically targeted at leading students and engineers who want to direct research in industry, or want to maintain significant links with industry in an academic career.

As of April 2013, 75 REs have entered the course. Their backgrounds range from recent graduates, through qualified architects to engineers with significant career experience. The REs are sponsored by a wide variety of sponsors from SMEs through to large PLCs; over 65 companies have sponsored EngD projects since the Centre's inception, including some that have entered novel partnerships with other sponsors.

The Centre's has been funded by the EPSRC. The EngD VEIV was founded in response to an EPSRC call to found new EngD centres after a few successful pilots in other centres. It has repeatedly been successful in securing new funding and has been rated as excellent in reviews. Unlike a traditional studentship, in the EngD model the industrial sponsor provides significant financial input to the project and provide resources to the student. In 2009 the EngD VEIV centre secured funding for fifty new projects in the years 2009 through 2013.

Mid-way through the 2008 grant, the EngD management recognized a need to enrich the programme's professional development component through a closer understanding of the Centre's broader R&D landscape. The first stage in this knowledge enrichment was supported by a survey among a range of companies working in the 'VEIV' technology sectors.

Methods

The survey comprised a questionnaire of 13 key questions, and was designed in direct consultation with the Centre's Industrial Advisory Board of senior industrial R&D specialists. For several questions, tick-box options were provided (including an option for 'other' and space for a written explanation). Participants were also invited to opt in to a follow-up interview. The questions are provided in *Table 1*, below:

Table 1. Survey questions

1. What technologies and applications does your company invest in?

2. What is % ratio of your R&D internal investment to your turnover?

3. Does your company benefit from collaborations with universities? (options pertain to modes of collaboration)

4. What is your R&D location strategy? (options pertain to locations and capabilities)

5. How does your company drive advances in R&D? (options pertain to funding and other resources)

6. What are the principal challenges of innovation in your field? (options pertain to pressures and externalities)

7. How do you organize your R&D? (options pertain to contractual arrangements and institutional partnerships)

8. Do you take advantage of current policy initiatives such as tax credits?

9. How do you derive scientific or technical knowledge?

10. What R&D partnerships have you participated in? (option to list them)

11. What partnership(s) would you like to form but are unable to? (option to list them)

12. How do you measure the economic success of your R&D activities? (options pertain to new business, process advances and other metrics)

13. How does your company develop its R&D talent?

Surveys were posted to 665 industrial R&D specialists. The specialists were found through a web search based on keywords stemming from the students' own work. Keywords were collated by compiling all available publications from 2001-2012, and extracting key themes from the materials. This was a considerable challenge, given the number and diversity of publications available. Once keywords were listed, the research assistant conducted a web search for any company, of any size or type, active in R&D in related sectors, mainly in the United Kingdom. Surveys were sent out with a four-week opportunity to complete and return them; a further postal reminder was sent out shortly before the four-week deadline.

The return rate was very low at just 19 surveys returned (2.85%), and most questionnaires were completed only partially. We consider this low rate and incomplete response telling, to some degree, of the current level of interest within industry of collaboration with academia (or, possibly, of the relevance of our questions), which is worth further investigation. Of the returned questionnaires, 5 respondents agreed to be contacted for interview (interview-based findings are not yet ready for publication). However, even this low number of responses has revealed a range of R&D activities, including limitations to advancement of these. Also represented are various kinds of engagement with universities, as well as frustrations in developing institutional partnerships and other support.

Findings

The responses were mainly from small enterprises, with just two coming from middle-sized companies. However, the study aimed to organize the respondents according to the ratio of turnover to investment in R&D. Interestingly, companies active in simulation applications were well represented among the respondents. Six of the 19 invest less than 10%, four 10% or more, and the remainder did not disclose a ratio. Of those investing less than 10%, these are active in the following sectors: 3D immersive visualisation, artificial intelligence, CAD, simulation, games and image geometry. Of those investing 10% or more, these are active in: simulation, computer vision, haptics and cyber security.

The survey questions were organized by R&D investment, the groups being *Undisclosed*, *<10%* and *>=10%*, summarized in *Tables 2-4*, as follows:

Table 2. Undisclosed group (n=6)

Does your company benefit from collaborations with universities?	Three companies hosted student interns, researchers and post-doctoral researchers. One company (a speculative investor) is involved with academic-based data only, and assists in interviews and setting study briefs. One is actively engaged in co-authorship of publications, and co-host workshops
What is your R&D location strategy?	As many of these companies are small enterprises, most report locating near to facilities or clients. Two report that cost and quality of life influence their location.
How does your company drive advances in R&D?	Three of the companies reported that graduate internships and doctoral studentships help drive R&D. Two reported their activities in social networks, demonstration events, conferences and publications
What are the principal challenges of innovation in your field?	Four of the companies reported lack of funding as being the principal challenge to innovation. Other leading challenges are pace of user adoption and access to talent. One respondent reported that the current economic climate prevailed against innovation, while another reported on the difficulty in prioritizing technology options against customer demands.

How do you organize your R&D?	Three of the companies cited direct full-time employment as their prime means of organising R&D, while three identified partnerships with other firms in the industry. Four cited networks for virtual out-sourcing. One company actively joined a contract with an academic institution, and is engaged informally in academia.
Do you take advantage of current policy initiatives such as tax credits?	There were no responses to the question pertaining to use of current policy initiatives.
How do you derive scientific or technical knowledge?	Three companies undertake secondary research (i.e. involving exploitation of others' primary findings). One company working in 3D web technologies undertakes laboratory or field research.
What R&D partnerships have you participated in?	One company had been involved actively in a KTP, one has provided supervision to a doctoral student, and one is involved with an on-going design project with a USA university. Other R&D engagements have stemmed from business relationships (i.e. as distinct to those with institutional support).
What partnership(s) would you like to form but are unable to?	One respondent reported that lack of time and limited knowledge precluded forming partnerships.

How do you measure the economic success of your R&D activities?	All the respondents in this group provided a broad range of measurements, including: patents and publications, media interest and buzz, increased revenues, market expansion, novel relationships, client engagements, process efficiencies, product enhancements, and profit-margin increments
How does your company develop its R&D talent?	Three of the respondents cited methods of development as being embedded in their business model (hence, reflected in business metrics). One company cited the use of student awards and one the business investment in research talent.

Table 3. <10% group (n=6)

Does your company benefit from collaborations with universities?	Five of the medium-investment companies cited hosting interns as the chief benefit of collaborating with universities. Four also cited co-funded and/or in-kind support for academic research (three of which also supported interns). One company hosting post-doctoral researchers, and one sent its researchers into academic institutions.
What is your R&D location strategy?	This question revealed a distinct, common theme for strategy as each medium-investment company locates its R&D close to its other facilities, with two companies variously citing the benefits of such a location strategy for the integration of knowledge into its business (as

	innovation, production and knowledge base).
How does your company drive advances in R&D?	A small number of common themes emerged in the responses. Five of the companies drive R&D chiefly through direct public and industry funding. Four cited demonstration events as key drivers, and two cited social networks. Three identified tracking client requirements, and one graduate internships.
What are the principal challenges of innovation in your field?	Four medium-investment companies identified pace of user adoption as being the chief challenge to innovation. External disturbance was also a key challenge for two. Other challenges included: limitations in supply, access to talent, pace of competition, lack of funding, lack of expertise, limitation in supply, economic uncertainty, standards, risk to business (defined as ROI to client.)
How do you organize your R&D?	Five medium-investment companies cited direct full-time employment as being their key method for organizing R&D. Three used joint contracts with academic institutions. Four used some form of outsourcing (based on networks or contracts). Two based this on partnerships with other firms in their specific industry.

Do you take advantage of current policy initiatives such as tax credits?	Only one company reported their taking advantage of tax credits, Technology Strategy Board and European Union initiatives.
How do you derive scientific or technical knowledge?	Four companies reported using lab- and field-based research, three secondary research, and one uses expert consultation.
What R&D partnerships have you participated in?	Five of the companies reported their involvement in formal R&D partnerships, including KTPs, a KTA, a TSB award and an FP7 award. One company cited several industry-based R&D partnerships.
What partnership(s) would you like to form but are unable to?	Each of the six companies in this category reported limitations to forming partnerships, citing business pressures.
How do you measure the economic success of your R&D activities?	Four of the six medium-investment companies identified an increase in revenue as the key indicator of success, and three cited product enhancements. Market expansion, client engagement and knowledge competitiveness were also cited. Other indicators include: patents and publications, process efficiencies, radical breakthroughs, supply-side improvements, media interest and buzz.

How does your company develop its R&D talent?	The six companies in this category cited a range of methods for developing R&D. These included investing in talent, using projects to provide training, incentive schemes, domain-specific problem-solving, and sending developers to conferences.

Table 4. >=10% group (n=6)

Does your company benefit from collaborations with universities?	Five of the companies in the high investment category identified a range of benefits from collaborating with universities. These included hiring academic consultants, hosting researchers such as post-doctorates, hosting interns, providing universities with co-funded or in-kind support, and taking advantage of TSB grants & vouchers.
What is your R&D location strategy?	High-investment companies identified some institutional relationships that influenced their location, including a historical relationship with a university, and access to classified military content. Others cited proximity to facilities.
How does your company drive advances in R&D?	The companies in this category cited a range of drivers for R&D, including: tracking client requirements, direct public funding, social networks & media, empirical market analysis, group critique, demonstrations & events, business training and patents.

What are the principal challenges of innovation in your field?	Lack of funding and economic uncertainty were identified as key challenges to innovation among this category. Other challenges include: external disturbances, lack of expertise, risk to business, pace of user adoption and internal conflict. One additional comment outlined the problem of keeping highly talented students, who often aim to start their own company. Another outlined the problem of identifying future market niches relating to current R&D.
How do you organize your R&D?	High-investment companies identified direct full-time employment and various forms of outsourcing as their key method in organising R&D, other methods included joint contracts with academic and industrial partners, including one working directly with vendors and another with agents across the EU and in Russia. One commented that highly qualified masters and PhD graduates benefitted their R&D.
Do you take advantage of current policy initiatives such as tax credits?	Only one takes advantage of TSB initiatives.

How do you derive scientific or technical knowledge?	Three companies reported using secondary research, one laboratory or field research and one expert consultation.
What R&D partnerships have you participated in?	Only one company responded, reporting involvement with a studentship and KTP schemes
What partnership(s) would you like to form but are unable to?	One company cited a possible project with an academic institution for technology trials. One comment maintained that difficulties in collaboration occurred because universities like formalised R&D that fits with funding programmes.
How do you measure the economic success of your R&D activities?	Five of the six companies in this category cited increased revenues as indicators of success in R&D, along with market expansion and product enhancement. Other indicators included: client engagement, radical breakthrough, profit-margin increments, knowledge competitiveness, novel relationships, process efficiencies, supply-side improvements and patents.
How does your company develop its R&D talent?	High investment companies reported that they develop talent by granting researchers autonomy in their work, providing continuous training and hands-on experience, as well as first-hand experience with semi-developed products.

Interpretation

While analysis of the results is limited by the low number of responses, three notable themes emerge. Firstly, it appears that many respondents execute their R&D by employing full-time staff and not through collaborations. In some cases the cost and opportunity cost of pursuing alliances or collaborations seems to be the principal issue. Secondly, many respondents indicated there were practical barriers in developing relationships with and making use of university resources (including students and recent graduates) and connections. Thirdly, respondents use multi-faceted methods to assess the success of their R&D. In these relatively high velocity technology spaces, the success of exploration is partly determined by 'soft' metrics of attention and 'buzz' as well as financial measures.

Given that the 'employment-based' approach to R&D execution points to firms having relatively narrow fields of interfirm R&D collaboration, firms may be relying on relatively narrow networks through which to diffuse their R&D discoveries and development. Therefore, feedback loops using such metrics may not be based on the optimal range of parties who might react favorably to the firms' developments.

On a general point of R&D investment, those companies reporting higher ratios of turnover to R&D investment also report broader and more intensive collaborations, compared with those reporting a low ratio. However, there appears to be little distinction in collaborative activities among those in the 'middle' R&D bracket and those in the 'higher'. This suggests that the range of investment of around 5-9% (ratio of turnover to R&D) represents best-value investment in terms of collaborative outputs.

16

Conclusions

These findings support the case that VEIV as a network player, matchmaker, facilitator and hub for diffusion of R&D progress in the sector may well have a contribution to make. The survey also revealed that the Centre's role as a catalyst may be limited to firms that have existing relationships with academic partners. Further research is needed to establish the dimensions of the role the VEIV might play, and to match these dimensions appropriately with available resources.

Implications for policy

The EngD VEIV Centre is one among a new generation of specialist centres for doctoral training, with a remit to catalyze partnerships and new knowledge. Hence, the researchers intend to incorporate these findings into the Centre's capabilities so as to strengthen the dynamic role of academic institution as a key driver of innovation within its broader R&D landscape. As most of the respondents did not report making use of policy initiatives, the EngD Centre could expand its remit to contribute to raising awareness of public and academic benefits to industrial R&D.

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