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Introduction

The aim of this article is twofold. Firstly, the new business concept of open and networked innovation is soundly discussed. The author presents fresh insights into the concept taken from the leading economic and management literature. Secondly, the case study on networked innovation in the United Kingdom is elaborated.

The author puts special emphasis on the British industry-university collaboration and its various forms, i.e. Industrial PhD (EngD) program, Industrial CASE program, Research Assistants Industrial Secondments (RAIS) scheme and the Royal Society Industry Fellowship. The author's claim is that the British industry-university collaboration is well-developed, however the EngD program lacks sound recognition and brand image among prospective doctoral students.

Theory of Networked Innovation

In the world of pervasive market changes, the demand for knowledge is rapidly increasing. However, the knowledge creation is a heavily decentralised process, i.e. there is no one knowledge pool that could be exploited by companies at any moment. Therefore, 'the innovation challenge has become how best to identify and use knowledge that is available both within and outside the company' (Sawhney, 2002, 26). This approach is an underlying principle of the **open innovation** paradigm.

According to Allio (2004) open innovation is gaining increasing attention and wider acceptance in business reality. The concept is used by a rising number of companies and soundly discussed throughout economic and management literature[1]. As we may read in the recent issue of Research Technology Management: 'the idea of open innovation existed in 1999 but was not on everybody's tongue' (Gwynne, 2007, 8). However, over several years the term gained sound attention in academic and managerial circles. Companies realised that: 'finding the knowledge is often a difficult search problem. Searching for the right person is a tough task. So rather than searching on the outside, you allow anybody to participate. It completely turns on its head the search process and the innovation process' (Gwynne, 2007, 8).

This radical switch in managers' thinking was aptly expressed by Gassmann (2006) who claims that opening the innovation process to users and customers became a major constituent of open innovation. However, the mainstream of literature underlines slightly different aspects of the discussed concept. Therefore, let me invite you to participate in the journey through recent research on the topic in order to capture the meaningful richness of the term.

In Chesbrough's article (Chesbrough, 2004, 23) we may read that: 'the open innovation paradigm assumes that firms can and should use external as well as internal ideas, and internal and external paths to market, as they look to advance their technology. Open innovation assumes that internal ideas can also be taken to market through external channels outside the firm's current businesses, to generate additional value'.

More detailed examination of the literature leads us to the **market oriented** definition of the open innovation (Zook & Rigby, 2002, 82): 'an approach that uses tools such as licensing, joint ventures, and strategic alliances to bring the benefits of free trade to the flow of new ideas'.

Another theoretical frame is delivered by Chesbrough and Schwartz (2007, 55) and so we may read that the open innovation means 'the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively'. As we can see the Chesbrough's understanding of the term puts an emphasis on both **inside-out** and **outside-in** strategic perspectives of a company (De Wit & Meyer, 2004). This means that growth through innovation (Harryson, 2006) may be triggered from the company's inside and at the same time pulled by the external environment. Let me call this capability the **strategic ambidexterity**[2] of a company, i.e. the talent to benefit from both the **resource-based** and **market-focused** entrepreneurial thinking (De Wit & Meyer, 2004).

The clear-cut distinction between the company and its external environment is strongly alleviated in another formulation of the open innovation. Henkel (2006, 953) explains it as a process of 'spanning firm boundaries'. This approach is supported by Prügl and Schreier (2006, 237). Their claim is that the 'boundaries between the firm and its surrounding environment are more porous, enabling innovation to move easily between the two'.

Christensen, Olesen and Kjær (2005) have identified the most important factors, which encourage companies to use the open innovation model. The increasing mobility of knowledge workers, flourishing number of venture capitalists and increasing scope of capable external suppliers stimulate company's openness and strive for business networking.

Whereas the open innovation remains a new holistic business philosophy, the **networked innovation** is rather its fulfilment, its effective form. Growth through innovation is, to my way of thinking, designed to fully benefit from the dynamics of networked structures. Networked innovation is then based on company's networks – 'made up of offshore suppliers, distributors, customers, freelance scientists, government and university researchers, and even competitors' (Fowles and Clark, 2005, 46). Networks, which combine different abilities, skills and backgrounds are more likely to accomplish an innovation than a homogenous team (Hellström & Malmquist, 2000). Within the networks, Neergaard (2002) identifies the **alpha entrepreneur** (leader or the leading company) with ability to build and use a web of partners strategically in founding and growing a new venture project (Myint et al., 2005). This insight corresponds with the definition of the networked innovation delivered by Hardy, Phillips and Lawrence (2003), who speak about the new knowledge created thanks to the collaboration of differentiated partners.

A more process-oriented understanding could be found in the paper written by Nambisan (2005, 29). In the dynamics of the networked innovation 'each individual firm contributes only part of the solution, and the components are ultimately brought together to create new products or services'.

A resource-based formulation is delivered in the seminal paper by Ahuja (2000, 426). He claims that the networked innovation is brought to the market place thanks to 'an interfirm collaborative linkage as a voluntary arrangement between independent organisations to share resources'. Further, Ahuja distinguishes networks contingent upon sharing a technology component from collaborative arrangements focused merely on sharing market assets or brand names (2000).

Innovation networks are often characterised by decoupled technology platforms, ongoing flexibility as an adaptability pattern, industry-specific processes as an applicability pattern, collaborative sales as a go-to-market strategy, customers as co-innovators (Radjou, 2004).

Networked innovation brings about a lot of advantages to today's business. As we may read in the literature (Pittaway et al., 2004, 137) 'principal benefits of networking' are 'risk sharing, obtaining access to new markets and technologies, speeding products to market, pooling complementary skills, safeguarding property rights when complete or contingent contracts are not possible'.

At the end of our introductory journey throughout the literature on open and networked innovation let me propose my favourite and overarching formulation of the discussed phenomena. The new business philosophy for **born global companies** could be understood as a system, in which organisations cooperate – combining the roles of inventors, transformers, financiers, and brokers – to match collectively global demand for innovation with worldwide supply (Radjou, 2005).

Open and networked innovation are then closely related business concepts. I would like to see them as complementary sources of **know-who based entrepreneurship** (Harryson, 2006). However, both terms underline slightly different aspects of corporate venturing. Open innovation remains a strategic frame, whereas networked innovation is rather its operational form. Comparative horizon on the discussed terms is given in the tables 1 and 2.

I believe that the both tables allow to craft clear-cut associations related to the discussed phenomena. I would like to stress only the issue of coordination mechanisms characteristic for the above conceptions. I feel very strongly that companies at the very start of open innovation journey administer only two coordination mechanisms, i.e. the price in relation to market decisions and the hierarchy in relation to organisational decisions. However, when the innovation network is growing, trust usually arises from interfirm linkages. Trust begins to play an extremely important role. Coexistence of a triad – market, hierarchy and trust – leads web of partners towards heterarchic organisation (Hagan et al., 2007). Horizontal interactions start to counterbalance firm's vertical alignment.

Table 1. Similarities between open innovation and networked innovation

Criterion	Open Innovation	Networked Innovation
Aim	Know-who based entrepreneurship[3]	Know-who based entrepreneurship
Output	Value creation for customers	Value creation for customers
Scope	Global	Global

Source: Own concept.

Table 2. Differences between open innovation and networked innovation

Criterion	Open Innovation	Networked Innovation
Managerial perspective	Strategic	Operational
Ambidexterity	Strategic	Organisational
Structure	Emerging	Organised
Coordination mechanism[4]	Market and Hierarchy	Market, Hierarchy and Trust
Rationale	Idea driven	Form driven

Source: Own concept.

Let me now discuss the role of science partners in the context of the open innovation paradigm. Industry-university collaboration may animate the process of innovation network formation and inject an impetus into the venture project. Some authors (Pittaway et al., 2004, 154) say that university partners 'play an important role as independent network brokers and intermediaries within business networks'. University allies usually support networked innovation through informal and personal networks (Pittaway et al., 2004). University researchers tend to be most important for radical open innovations (Fritsch, 2001). Laursen and Salter (2004) refer to the supporting role of university allies in search processes for new product ideas, new forms of organisation and solutions to existing problems. Kaufmann and Tödtling (2001, 791) claim that 'crossing the border to science increases the diversity of firms' innovation partners and respective innovation stimuli, which in turn improves the capability of firms to introduce more advanced innovations'.

What is more, **industry-university collaboration** brings great benefits not only at the level of exploration but also at the level of idea exploitation. Rigorous analysis of 2457 alliances undertaken by 147 biotechnology firms delivered by George, Zahra and Wood (2002, 577) shows that 'companies with university linkages have lower research and development expenses while having higher levels of innovative output'. Another study of bio-tech firms (Murray, 2004, 643) demonstrates that 'academic scientists contribute not only human capital but also social capital[5] to entrepreneurial firms'.

The important question is, however, under what conditions the above benefits from industry-university collaboration may be fully appropriated. Econometric analysis made by Veugelers and Cassiman (2005, 355) shows that cooperative arrangements between business and academia are successfully formed 'whenever risk is not an important obstacle to innovation'. This means that the more hazardous is the project, the more difficult is to make university researchers join it. This is a really tricky dilemma since industry-university collaboration may be extremely helpful in projects of Knightian uncertainty (Beunza & Garud, 2004) when the exploration phase is of the greatest importance. This applies to open and networked innovations. Therefore, to my way of thinking, open and networked innovation can be supported by industry-university collaboration in case of non-structured, advanced or radical technological challenges, for they lead to better results at lower costs through resource sharing under conditions of trust. However, we should remember the outlined trade-off, i.e. the more industry-university cooperation is needed, the more difficult is to form it.

The British Model of Industry-University Collaboration

The Engineering and Physical Sciences Research Council (EPSRC) is the most powerful UK government agency investing around Ł 740 million a year in the development of the British research (EPSRC's website). EPSRC administers four different programs, which aim at building links between universities and the industry. Degree level students may benefit from the **Engineering Doctorate (EngD)** or the **Industrial CASE** program. 'Another option for those that are already conducting academic research is the **Research Assistants Industrial Secondments (RAIS)** scheme' (Ravilious, 2004, 16). Established industrial scientists may enrol for the **Royal Society Industry Fellowship,** which gives the opportunity to attend a course at a university or work with academics on an industrial project.

In this paper, I would like to focus on the Industrial PhD program for Great Britain. Popularity of the Industrial PhD is a very good measure of density of country's industry-university collaboration. Therefore, I will focus on the British Engineering Doctorate scheme. However, before I turn to an in-depth analysis of the EngD project, let me briefly outline the other three initiatives in order to draw the complete landscape of the British cooperation between business and academia.

Industrial CASE is a three and a half year postgraduate award allocated to companies. 'The aim of the award is to enable companies to lead projects with an academic partner of their choice' (EPSRC's website). The company has to commit to the Industrial CASE student and allow him or her to spend at least three months on its premises to conduct research. One third of project costs are covered by the awarded company. This amount usually accounts for Ł 21,000 (EPSRC's website).

Research Assistants Industrial Secondments scheme 'aims to help researchers (already with doctoral degree) transfer the knowledge they have gained during research across into an industrial or business environment' (Ravilious, 2004, 17). The Royal Society Industry Fellowships are oriented on experts working in the industry and facilitate the transfer of practice-focused knowledge back to universities.

The EngD scheme was launched in 1992 'as a response to the needs of industry and the demand for industrial qualifications coming from students' (EPSRC, 2002/3, 1). An university, which has successfully applied for the EngD program has to establish a centre that becomes a hub for relations between the university and companies. Each newly created centre is allotted up to Ł 3.5 million to set up a top quality Industrial PhD course (ibidem). Students enrolled on the course are called **research engineers (REs)** and are assigned to one academic and one industrial supervisor. Research engineers are expected to spend 75 per cent of their time devoted to studies on the company's premises working on a specific business problem. The rest of the time students attend university courses, which constitute a perfect blend of applied engineering and management subjects (ibidem).

The EngD graduates are extremely attractive to companies. They posses an unique set of skills. To quote Dr Stephen Wise, who studied at the Cranfield University's EngD centre: 'the EngD was extremely useful both from an academic and personal viewpoint and provided benefits that were not available elsewhere' (EPSRC, 2002/3, 3).

Market prospects of EngD graduates are fabulous. Over fifty per cent of them earn between Ł 20,000 and Ł 30,000 monthly and the rest even up to Ł 60,000 on the monthly basis[6] (EPSRC, 2002/3, 3).

Let me now review the basic **competitive advantages** (Porter, 1985) of the British Industrial PhD program over traditional academic offers. The advantages have been identified by the program stakeholders, i.e. current and past research engineers, industry experts and academics (SMA, 2006).

First of all, 'the EngD develops innovative thinking while tackling industry problems' (SMA, 2006, 7). Secondly, the majority of stakeholders agreed that EngD is actually more valuable in the market place than traditional PhD in engineering. What is more, seventy per cent of academics and eighty per cent of industry supervisors claim that the EngD fosters communication between academia and business. This result heavily corresponds to the widespread opinion that the EngD strengthens the links between the university research and industrial needs. Finally, the EngD allows to flexibly merge top quality teaching in engineering with the MBA level courses, develops students' nexus of contacts within the industry of their highest interest and brings higher funding than traditional PhD stipends. Financial dimension of the EngD will be covered in detail in the further part of the paper. Identified drawbacks of the EngD, i.e. frequent interruptions of work dedicated to the company's problem solving due to course obligations seem to be fully compensated by the above benefits of the program (ibidem).

Since introduction of the EngD[7] 1,230 research engineers have been enrolled, sponsored by over 510 different companies (EPSRC, 2007). In the same period (1992–2006) about 34,950 scholars graduated from the British universities with traditional PhD degree in the field of engineering or physical sciences (UK GRAD). Therefore, we may say that over the last fifteen years 3.5 per cent of all doctoral students in the UK interested in engineering and physical sciences chose Industrial PhD route.

Let me now draw your attention to the universities participating in the EngD program. The key data are presented in the table below. Each university is characterised by the number of research engineers (both students and graduates) and the core area of Industrial PhD studies. The total number of the EngD centres is twenty. However, we should bear in mind that some universities administer several EngD centres. On the other hand, some centres are supported by more than one academic institution.

Table 3. The most active universities in the British industry-university collaboration

University	Area of research	Number of research engineers
University of Birmingham	Chemical engineering, Metallurgy and materials	63
Universities of Bristol and Bath	Mechanical engineering	3
Cranfield University	Enhanced engineering	150
Heriot-Watt University	Photonics engineering	18
Imperial College London	Nondestructive evaluation	19
Universities of Edinburgh, Glasgow	Electronic system design	25
Loughborough University	Construction engineering	67
University of Manchester	Nuclear engineering, Process and product engineering	169
University of Newcastle upon Tyne	Power electronics	22
University of Southampton	Transport and systems engineering	51
University of Surrey and Brunel University	Environmental technology	162
University of Wales Swansea	Steel technology	176
University College London	Network engineering, Virtual environments	198
University of Warwick	Manufacturing systems engineering	107

Source: Own concept.

The listed in Table 3 Industrial PhD centres have cooperated so far with 513 companies (EPSRC, 2007). However, I would like to highlight here the role of the most active business partners, i.e. companies which have supported at least six research engineers from the launch of the program. The most active companies have collaborated with about forty per cent of the British Industrial PhD students and have profound influence on program's quality and recognition in the market. The key industrial partners will be listed in the alphabetical order. The most involved firms in the development of the British industry-university collaboration are then: Airbus UK Ltd, Arup Group Ltd, BAE Systems, BHR Group Ltd, BMW Group, British Telecommunications Plc, Buro Happold Ltd, Corus UK Ltd, EA Technology Ltd, Econnect Ltd, GlaxoSmithKline PLC, Hewlett Packard plc, Imerys Minerals Ltd, Jaguar and Land Rover, Land Rover Group Ltd, Lonza Biologics plc, Mott Macdonald UK Ltd, National Physical Laboratory, QinetiQ Ltd, Rolls-Royce plc, Rover Group Ltd, Silsoe Research Institute, Sira Ltd, Thames Water Plc, TRW Automotive Technical Centre, TWI Ltd, Unilever Plc, WM Engineering Ltd, WRC Plc (EPSRC, 2007).

In the following part of the paper I would like to present two examples of the British industry-university collaboration. The first will be devoted to the work of Katy Milne, the Imperial College London EngD student, who is currently doing her research in the Rolls-Royce nondestructive laboratory in Derby. Milne started her Industrial PhD studies in 2005. She describes her project and collected experience in the newsletter published by the Imperial College London: 'The challenges are numerous. If working with a derisive gang of veteran nondestructive technologists was not enough, I have to learn to negotiate my way around the company, balance the demands of the project with coursework and attempt to digest a huge amount of fresh knowledge; this occasionally involves going back to the fundamentals I have not studied since school' (Milne, 3).

Milne's project is to measure the sensitivity of techniques and simultaneously look into methods for characterising crack closure and for the imaging and automatic recognition of fluorescent indications. She is emphasising that in the Rolls-Royce laboratories she is exposed to the new products at all points of the life cycle, so she is able to make her contribution to the development of new materials, manufactured parts and in-service issues (ibidem). Both sides, i.e. students and Rolls-Royce experts openly cooperate giving rise to the emerging processes of cross-fertilization. The ultimate goal of Milne's Industrial PhD studies is to design an unique and innovative ultrasonic transducer (ibidem), which could be applied in the Rolls-Royce architecture. She has to submit her EngD thesis on the ultrasonic transducer by the end of 2009.

The other very promising project is run by the Heriot-Watt University, the Photonics group. One of the EngD students, sponsored by BAE Systems, works on an accurate and agile beam steering technology, which could be successfully commercialised in the following disciplines: remote sensing, optical microscopy and mobile communication platforms (Heriot-Watt's website). The engineering puzzle of beam steering optimisation has been actively researched over the past two decades since the existing solution (gimbaled mirror) is very slow and inaccurate. Development of flexible and precise technology based on organic non-linear optical materials could trigger a breakthrough innovation in space-based and terrestrial optical communications in the next few years. The latter example corresponds to my claim from the previous section of the paper that industry-university collaboration may be used to tackle advanced and challenging engineering puzzles.

Let me now focus on the financial side of the EngD program. Each centre implemented slightly different pattern of funding. However, let me elaborate upon a representative solution applied by the University College London (UCL, 2003). New Industrial PhD students (first-year scholars) are sponsored by a selected industrial partner (Ł 15,250 per annum on average). However, in the same year, EPSRC pays Ł 10,000 to the company in order to balance incentives' structure on both sides of the agreement. In the next three years, as the research engineer brings more value to the selected partner, it is only the company that pays Ł 15,250 per annum to the student and Ł 2,940 per annum to the university he or she comes from (ibidem). To draw relevant comparisons, the traditional PhD students in the UK in the area of engineering and physical sciences are supported solely by the EPSRC, i.e. the sum of Ł 12,300 is granted for three years (EPSRC's website). As we can see, Industrial PhD solution is much more financially efficient for the government and the EngD candidates are better incentivised to conduct their research due to longer time of funding and moderately higher amounts.

Managing Industry-University Collaboration for Growth through Innovation

Some claim that the British industry-university collaboration is well-developed, however the EngD program lacks sound recognition and brand image among prospective doctoral students. The British Industrial PhD scheme is of the highest quality in terms of contribution to the industry and scholars' personal development. The problem is however how to inform students about advantages of the EngD and great benefits, which could be attained from their participation.

I strongly believe that the number of scholars who choose the British Industrial PhD route could be significantly increased and be much more higher than 3.5 per cent of the target group as it used to be over the last fifteen years. However, before I suggest enhancements of the EngD program let me draw your attention to the overall degree of industry-university collaboration in the Great Britain.

The degree of industry-university collaboration in the UK is high because of huge diversity of interactions between business and academia (D'Este & Patel, 2007). This variety comes not only from patenting, licensing and formation of start-up companies but also from personnel mobility, informal contacts, consulting relationships and joint research projects. Patenting and spin-offs are only a minor part of the richness of industry-university collaboration (Arundel & Geuna, 2004). The above mentioned variety allows to 'interrelate the worlds of research and the worlds of manufacturing and product application' (D'Este & Patel, 2007, 1297). It integrates science and technology and triggers growth through innovation in the Great Britain.

D'Este and Patel (2007) have identified several drivers of business-academia interactions specific for the UK. Hypothetic factors, i.e. commercial orientation of universities, department characteristics and individual characteristics of researchers have been carefully examined in thorough statistical analysis. Raw data have been derived from a large-scale survey conducted among the British university scientists that aimed at obtaining information about their interactions with business partners (ibidem). The results show that individual characteristics play the most important role in explaining the variety of **business-academia linkages**. What is more, 'those researchers with a record of past interaction are more likely to be involved in a greater variety of interactions with industry' (ibidem, 1309). Academic status also matters. 'Individuals who are well-established in their scientific career are more likely to capitalise on their reputation to increase their engagement in commercialisation activities' (ibidem, 1309).

We may thus say that the high degree of diversified industry-university collaboration in Great Britain exists because academics and businessmen successfully internalised the idea of know-who based entrepreneurship (Harryson, 2006), i.e. their open attitude gives impetus to dense transfer of knowledge between the worlds of science and commercialised technology. The richness of interrelations between these two worlds has been summarised in the table below.

Table 4. Involvement of university researchers in various forms of industry-university collaboration in the UK (per cent of researchers engaged over the period 2002–2003)

Personal meetings	Consultancy	Joint research	Training	Creation of physical facilities
65	56.3	44.6	42.5	20.8

Source: (D'Este & Patel, 2007).

Let me now suggest some possible enhancements of the British model, and particularly the current EngD scheme. When it comes to the general research policy of the British government less emphasis should be put on universities and more on researchers since they really give rise to growth through innovation (D'Este & Patel, 2007). Policies should then target creation of stable networks of potential users of scientists' research. Therefore, the current policy, which is oriented on supporting the whole universities is definitely too much centralised and limits the know-who based entrepreneurship. Nationwide policy should be more sensitive and treat researchers and not universities as a point of reference. Furthermore, authorities should help the British Industrial PhD program to gain more recognition among doctoral students as the EngD is a real embodiment of a vivid and dynamic industry-university collaboration and cross-fertilization. 'EPSRC should commission external professional help in defining a clear brand for the EngD based on its core principles and its distinctive nature' (EPSRC, 2007, 15). What is more, clear communications and marketing strategy should be established to promote the EngD scheme to potential new sponsors, business sectors and research engineers (ibidem). To put it brief, denser network of various stakeholders should be woven around the project to increase its recognition and perceived attractiveness. Professional accreditation of the program could be also introduced in order to craft 'a clearly visible path for research engineer through to chartered engineer status' (ibidem).

On the other hand, the British companies should continue its increasing involvement in business-academia partnerships. Firms should strive to institutionalise the internal culture of innovation (Kay Vona & DeMarco, 2007). This concept postulates a creation of various organisational incentives, which stimulate corporate openness and ability to learn. After all 'many of today's business leaders believe that innovation, which is more open, collaborative, multidisciplinary and global than ever before, holds the key to business success for the foreseeable future' (ibidem, 28).

Summary

In the article the author analyzed phenomenon of industry-university collaboration in the United Kingdom. The nexus of twenty Engineering Doctorate centers in the Great Britain was thoroughly examined in the core part of the paper. The major benefits for business and academia, the most typical areas of research and the interesting examples of co-created inventions were discussed. Managerial implications and author's suggestions about possible enhancements of the British model were drawn in the final paragraphs.

The British science policy-makers should then strive to design the appropriate system of incentives targeted towards creation of stable networks of potential users of scientists' research. Secondly, authorities should help the British Industrial PhD program to gain more recognition among doctoral students. Thirdly, clear communications and marketing strategy should be established to promote the EngD scheme to potential sponsors, business sectors and research engineers.

The British companies should continue its increasing involvement in business-academia partnerships. Firms should strive to institutionalize internal culture of innovation. This concept postulates a creation of various organizational incentives which stimulate corporate openness and ability to learn.

Notes

[1] Selected articles are quoted by the author as references at the end of the paper.

[2] As opposed to organisational ambidexterity, which means an effective use of creativity and hierarchy mechanisms in the phase of development of new technology. Ability to merge exploration and exploitation activities is then here underlined.

[3] Concept is elaborated upon in the book written by Harryson (2006).

[4] Very interesting discussion on coordination mechanisms can be found in: Adler, P. (2001) 'Market, Hierarchy, and Trust: The Knowledge Economy and the Future of Capitalism', Organization Science, vol. 12, no. 2.

[5] Distinction between terms of human and social capital can be found in: Coleman, J. (1988) 'Social Capital in the Creation of Human Capital', American Journal of Sociology, vol. 94, pp. 95-120.

[6] Data based on the survey carried out among graduates from the Manchester EngD centre between 1996 and 2001. Source: www.epsrc.ac.uk.

[7] Program established in 1992.

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