



THE UNIVERSITY *of* EDINBURGH

Edinburgh Research Explorer

A typology of research training in university-industry collaboration: The case of life sciences in Finland

Citation for published version:

Chiang, I 2011, 'A typology of research training in university-industry collaboration: The case of life sciences in Finland', *Industry and Higher Education*, vol. 25, no. 2, pp. 93-107. <https://doi.org/10.5367/ihe.2011.0032>

Digital Object Identifier (DOI):

[10.5367/ihe.2011.0032](https://doi.org/10.5367/ihe.2011.0032)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Publisher's PDF, also known as Version of record

Published In:

Industry and Higher Education

General rights

Copyright for the publications made accessible via the Edinburgh Research Explorer is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The University of Edinburgh has made every reasonable effort to ensure that Edinburgh Research Explorer content complies with UK legislation. If you believe that the public display of this file breaches copyright please contact openaccess@ed.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.



A typology of research training in university–industry collaboration

The case of life sciences in Finland

Kuang-Hsu Chiang

Abstract: *This paper examines the educational implications of research collaboration between university and industry for the research training of doctoral students. It is concerned with the issues of how research training is constructed in such collaborations and what might be the effects of collaboration on doctoral students' learning. The study adopts a knowledge perspective. Three different dispositions of knowledge are identified: 'expert', 'utilitarian' and 'commercialized'. Doctoral students' experiences were examined in relation to two aspects of research training – industrial involvement in supervision and academic freedom – in university–industry collaboration in the field of life sciences. Thirty-five in-depth interviews were carried out at BioCity Turku in Finland with 16 doctoral students, 14 of their supervisors and 5 PhD graduates. Four major types of PhD research collaboration were discovered, characterized as 'Financial', 'Interactive', 'Kangaroo' and 'Appendant'. The significance of each type is discussed in relation to different knowledge dispositions. Drawing on the research findings, suggestions are offered for constructing successful research training programmes through university–industry collaboration.*

Keywords: *R&D collaboration; research training; doctoral students; industrial scientists; life sciences*

Dr Kuang-Hsu Chiang is with the Moray House School of Education, University of Edinburgh, Paterson's Land, Holyrood Road, Edinburgh EH8 8AQ, UK. E-mail: kuang-hsu.chiang@ed.ac.uk.

The initial wave of policy research in the area of university–industry collaboration has produced a reasonably good understanding of how academia can relate to industry, the benefits and drawbacks of such collaboration and what obstacles must be overcome if the collaboration is to be successful (Veugelers and Cassiman, 2005; Mendoza and Berger, 2008; Geuna and Muscio, 2009; Martin, 2000; Lambert, 2003; Crespo and Dridi, 2007; Blumenthal, 2003; D'Este and Patel,

2007). Although such collaboration is important for both the university and industry, it can cause some concerns. For example, Professor Roy Harris declared in a speech at the University of Oxford: 'Most of the current evils of the world, from the arms trade to the systematic destruction of natural resources, rely on technologies that would not exist but for the active collaboration of people with the highest academic qualifications' (Times Higher Education, 2009).

What seems lacking in efforts to explore university–industry collaboration is an attempt to investigate the educational implications of such collaboration at doctoral level. The majority of studies, which generally concentrate on the educational dimension, tend to focus on training programmes, co-developed by both sides, at undergraduate level (Meredith, 2008; Harrison *et al*, 2007; Thomas and Busby, 2003). Little attention appears to have been given to the impact of university–industry collaborations on research training at doctoral level. This seems unfortunate, given that many R&D projects are actually carried out by doctoral students who play a central role in such collaborations.

This paper therefore addresses two important questions: (1) how is research training constructed within university–industry collaboration?; and (2) what impacts can such collaboration have on doctoral students' learning? Answers were sought by studying research training in R&D collaborations in Finland, from the perspective of knowledge, in the discipline of life sciences.

According to the OECD (2008), Finland is one of four countries (the others are Sweden, Japan and Korea) where in 2006/2007 the R&D-to-GDP ratio was greater than 3%, well above the OECD average of 2.3%. Since 1998 Finland has continuously been one of the top two OECD countries having the largest gross domestic expenditure on R&D for more than a decade (OECD, 2009). In 2007, it had a gross domestic expenditure of 3.47% on R&D, very similar to that of Sweden (3.63%) (*ibid*). In order to encourage research collaboration between academia and industry, one of the initiatives taken by the Finnish government is to offer R&D funding through the National Technology Agency (TEKES). Thus, for example, in university-initiated TEKES projects, industry is not required to make significant financial contributions: the projects are heavily subsidized by the government.

This paper is structured as follows. First, the knowledge perspective used is presented, by analysing distinct knowledge dispositions held by university and industry. The research training dimension of university–industry R&D collaboration is then explored, followed by an account of an investigation in the context of Finland which highlights important factors for successful research training in such collaboration.

A knowledge perspective

One key element which engages both academia and industry in R&D collaboration is knowledge. It is therefore important to understand how each position themselves with regard to knowledge and how such 'knowledge dispositions' relate to academic freedom and

'open science'. Three distinct knowledge dispositions are identified in this context: 'commercialized', 'utilitarian' and 'expert'.

Gibbons proposes two modes of knowledge: Mode 1 and Mode 2 (Gibbons *et al*, 1994; Gibbons, 2000). This distinction arises mainly from a socio-epistemological perspective – through 'the context of discovery, the role of the disciplines, the skill mix of researchers and forms of organisation they adopt, social accountability and reflexivity of the researchers and quality control' (Gibbons, 2000, p 159).

Mode 1 knowledge refers to issues within the academic community: it is known as traditional knowledge, which is generated in disciplines and is academic-driven. Mode 2 knowledge is characterized by its applicative nature and social obligations, and is created out of wider interests. It signifies a close and interactive link between science and society and is usually driven by needs or problems arising outside academia, such as social and economic concerns. Mode 2 is therefore 'more socially accountable and reflective' than Mode 1 (Gibbons, 2000, p 160).

In Gibbons's analysis, however, it seems that the ontological aspects of science are overlooked. Among them there are two important dimensions: academic freedom and 'open science'. It is found that if knowledge is examined from these two dimensions, three 'ideal types' of knowledge dispositions can be identified: commercialized, expert and utilitarian. Embedded in the commercialized disposition are functional intentions and the concept of profit: this is a disposition usually held by the industry (Zucker *et al*, 2002). Knowledge which does not serve an immediate function or does not have the potential to make a financial profit is, to a large extent, not recognized. What is generated from this disposition is a type of scientific culture which stresses secrecy and end-products in order to protect its own commercial interests and preserve its competitiveness in the market. The emphasis on secrecy makes commercialized knowledge a closed scientific system and the value of knowledge is judged only by the likely financial profits. Furthermore, due to its applicative nature, the commercialized knowledge disposition is characterized by its external references – the link between science and commercial markets. The extent of external references of scientific enquiries indicates the degree of academic freedom: total academic freedom can be exercised when self reference of knowledge is sufficient and no external reference is required. The presence of strong external references therefore indicates seriously constrained academic freedom.

In almost the completely opposite position, the expert knowledge disposition signifies traditional

'legitimate knowledge' in universities, which highlights the disinterested pursuit of knowledge (Merton, 1968; Evans and Packham, 2003). By distancing itself from societal and economic values, the university represents itself as an independent critic of society (Krimsky *et al*, 1991; Vest, 2006, p 8). Such a disposition is characterized by the possibility of exercising full academic freedom and by open communication. In contrast to the commercialized disposition, which is validated through its external commercial references, the validation of expert knowledge does not need other references. The value of legitimate knowledge lies in itself: it is sufficient for it to be self-referred. The non-requirement for external references bestows unconstrained academic freedom on such a disposition. Unlike the commercialized disposition, which has the principal aim of generating financial profits, the ultimate goal of expert disposition is the pursuit of truth. It is therefore distinguished by its open science culture – that is, the free exchange of ideas. There is no secrecy with regard to new knowledge, discovered or created, once it is published: ideas are freely exchanged.

However, this traditional view of disinterestedness is challenged in contemporary universities, which are characterized by their multiple logic systems (Mendoza and Berger, 2008). Unlike traditional universities, where knowledge is mainly academic-driven, contemporary universities accommodate different types of knowledge which can be trans-sectoral and produced out of and for wider interests. To some extent this corresponds to Gibbon's Mode 2 knowledge (as stated above). From the perspective of organizational culture, the multiple logic systems include institutional, social and industrial logics in the case of academia (Mendoza and Berger, 2008). It is this coexistence of various logics in academia that makes contemporary universities different and explains why they tend to engage more with society and the world at large than is the case with so-called traditional universities.

This new logic facilitates utilitarian knowledge which is characterized by its social or public-good intentions. This entails diffusion of knowledge and public engagement and, to some extent, it corresponds to Ziman's discussion of 'instrumental science' (Ziman, 2003) or Slaughter and Rhoades' concept of the 'academic capitalism knowledge regime' (Slaughter and Rhoades, 2004). This disposition of knowledge in the university abandons the distance traditionally maintained between academia and society. Instead, it adopts an interventionist role in society, actively engaging through scientific intervention either in the form of services such as foundations, learning societies, community support and joint research projects; or as

products, such as technology and joint research centres. The intention is to influence, or be influenced by, society.

It is important to highlight the subtle but important differences between this university-based utilitarian disposition and the commercialized disposition which is usually found in industry. Unlike industry's commercialized knowledge, which focuses mainly on financial profit, the utilitarian disposition has different and wider intentions. Based in academia, it is initially driven by a belief in 'open science' or 'public good' knowledge – that is, to share its potentially beneficial results with society at large; and this is almost the exact opposite of industry's commercialized disposition. The utilitarian disposition has connotations of public-spiritedness and social conscience; this manifests itself in particular in the social sciences. It is concerned with the social and cultural impacts of such exploitation of knowledge: the financial outcomes come as a by-product. With the addition of the influence of commercialism, this disposition can further develop into different varieties such as the 'solidarity stance', which is linked to its original social intention, and the 'entrepreneurial stance' (Clark, 1998; Etzkowitz *et al*, 2000; Crespo and Dridi, 2007) which is closer to the commercialized disposition.

Although the university-based utilitarian knowledge, as with industry's commercialized knowledge, is linked to functionalism – and thus both make external references – validation of the former is through social references and of the latter through commercial references. These two propositions also differ on the point where utilitarian knowledge and traditional legitimate knowledge dispositions merge – that is, open science. Both traditional and utilitarian academics place a high value on open scientific communication through publication, public meetings and conferences (Cohen *et al*, 2002). In contrast, the commercialized disposition places greater stress on secrecy. The secrecy of commercialized knowledge held by industry, together with its strong financial intention, is incompatible with the concept of open science shared by traditional expert knowledge and utilitarian knowledge. Issues such as intellectual property, scientific communication, credibility of scientific results and conflicts of interest become a serious concern (Pritchard, 1996; Glaser and Bero, 2005; Krimsky, 2004; Prigge, 2005). Suspicion of acts such as suppression of results, threats to human health, or even life, and deliberate deceit were raised in R&D collaboration (Olivieri, 2003; Weatherall, 2003; Friedberg *et al*, 1999 cited in Boyd and Bero, 2000). The tension between commercialized and utilitarian knowledge is caused by the fact that scientific

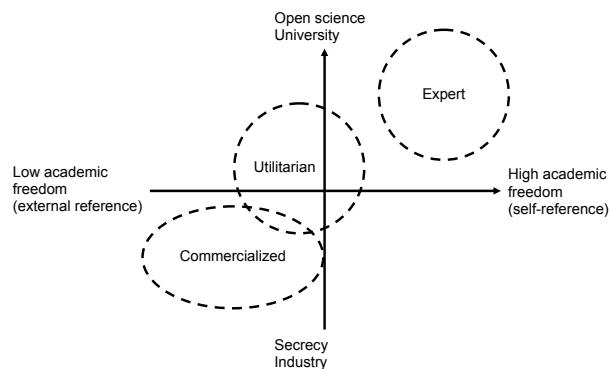


Figure 1. Three knowledge dispositions.

knowledge is required ‘for a variety of public purposes, such as political discourse, legal disputation, and consumer protection’ (Ziman, 2003), but such knowledge can be manipulated by vested interest as ‘partial results are dressed up as objective knowledge’ (Evans and Packham, 2003).

From the above discussion, the relative positions of the three different knowledge dispositions differentiated along two dimensions, academic freedom and open science, are presented in Figure 1. Academic freedom is related to the degree of self or external reference. High academic freedom is marked by its self-reference or non-requirement of external reference, whereas low academic freedom refers to high level of external references. Open science, which usually manifests itself in academic research, is in opposition to the secrecy which usually permeates in industry.

The expert knowledge disposition, characterized by its high levels of self-reference and open science, is located in the first quadrant (upper right region) in Figure 1. The commercialized knowledge disposition, in the third quadrant (lower left), is characterized by its high levels of external reference and secrecy, is placed almost exactly opposite the expert disposition. The utilitarian disposition, characterized by its external reference but open science intentions, is situated mostly in the second quadrant. Note that the borderlines of these dispositions are neither fixed nor arbitrary. The classification depends on the extent to which the disposition relates to academic freedom (self-reference) and open science. In other words, the nature of these dispositions is not exclusive. For example, ‘expert knowledge disposition’ does not mean that it refuses to recognize the possible utilitarian or commercialized purposes of knowledge: it simply means that it emphasizes a higher degree of open science and academic freedom than the other two.

Doctoral students and knowledge creation in R&D collaboration

Doctoral students who contribute to the production of knowledge in universities (Enders, 2002; Kyvik and Olsen, 2008; Thune, 2009a) also play a central role in R&D joint university–industry projects. For the universities, the importance of doctoral students is expressed in two ways – being at the frontier of utilitarian knowledge and acting as both a missionary and witness of the knowledge transfer process (Slaughter *et al*, 2002). The work conducted by doctoral students in R&D collaboration is innovative and, in an applied sense, self-characterized: legitimate scientific knowledge is produced and its academic value is recognized. In this sense, doctoral students are the pioneering producers of utilitarian knowledge. Furthermore, as a result of their fundamental role in R&D collaboration, doctoral students are regarded as a ‘gift’ from the university to industry (*ibid*). Their mission is to transform academic knowledge into something useful for industry, which corresponds to Edquist’s (1997) idea of knowledge translation. In addition, doctoral students are also the witnesses of this knowledge transfer process. In R&D collaboration they are possibly the only participants having direct experience of working in both academia and industry. Being both subject and witness of this process is considered to be intrinsically valuable knowledge for both doctoral students and the wider scientific community in universities.

For industry, doctoral students are important in two ways. First, they bring fresh ideas to existing knowledge in industry. Having people from universities working in a company not only develops the company’s stock of scientific knowledge but also increases the ‘absorptive capacity’ of the company (Vinding, 2004). More importantly, it creates a ‘spill over’ effect (Jaffe *at al*, 1993 cited in Thune, 2009b; De Bondt, 1997; Lynskey, 2010) which can lead to a change in the company’s scientific culture such that it becomes familiar with the deployment of new knowledge. According to Vinding (2004), the company can familiarize itself with the process of recognition, assimilation and application of new knowledge, which brings about radical innovations, through interacting with doctoral students.

For both sides, the significance of doctoral students lies in their unique role as the executors of the R&D projects and being part of the social capital. Both academia and industry rely on doctoral students to conduct the R&D projects (Behrens and Gray, 2001) – for example, with work in the laboratory, testing new ideas, experimenting with different or novel methods and collecting, analysing and interpreting data. Apart

from their significant contribution to the scientific work, they also help establish social capital on both sides. The scientific and social network links created or strengthened by doctoral students through supervisory relationships, having colleagues on both sides and recruiting graduates are valuable for both the university and industry (Liebeskind *et al.*, 1996; Slaughter *et al.*, 2002). They generate trust and familiarity and help to avoid misconduct in the collaboration process (Granovetter, 1985).

Research design

To explore the educational implications of R&D collaboration, the discipline of life sciences at BioCity Turku Finland was chosen as the area of study. Thirty-five in-depth interviews were carried out, in 2004, with 16 doctoral students, 14 of their supervisors and five doctoral graduates, all associated with biotechnology or pharmaceutical companies. The PhD students were asked the following questions.

- (1) 'In what way does industry/company involve in your PhD research project?
- (2) 'How does industry/business influence the following aspects of your research training?'
- (3) 'To what extent and in what way?'

The topics considered were supervision, the research project (design of research, academic freedom, intellectual property), research training, the research environment for doctoral students (for example, research facilities, research culture, industrial network for students) and career development. This paper focuses on the analysis of the experiences of the 16 doctoral students: information on their year of study, gender and life science subject areas is summarized in Table 1.

The Biocenter Finland was formally established in 2007 to facilitate R&D collaboration between universities and industry in biosciences and biomedicine. It has two main features. First, it is a combination of private enterprises and universities: one of its objectives is the commercialization of research findings. It creates a 'technology platform' for both sides, with the intention of developing a 'nation-wide knowledge base' for the development of biosciences in Finland.¹ The second feature is its strong emphasis on research training. Many programmes organized by Biocenter target doctoral students and young investigators and so there is a focus not only on the research training but also on career development.

BioCity Turku, established in the early 1990s, is one of the six member institutes of Biocenter Finland.² It is characterized by its Triple Helix of research, industry and education and it aims to promote collaboration

Table 1. Year of study, gender and academic fields of the 16 cases.

	Year of study	Gender	Academic subjects in life sciences
Case 1	4th	M	Industrial chemistry
Case 2	2nd	F	Oncology and radiotherapy
Case 3	6th	F	Organic chemistry
Case 4	5th	M	Prosthetic dentistry
Case 5	4th	M	Biochemistry and food chemistry
Case 6	4th	M	Industrial chemistry
Case 7	3rd	M	Industrial chemistry
Case 8	3rd	M	Industrial chemistry
Case 9	5th	F	Chemical engineering
Case 10	5th	F	Pharmacology and clinical pharmacology
Case 11	3rd	M	Medical chemistry
Case 12	3rd	M	Anatomy
Case 13	1st	F	Biochemistry and pharmacy
Case 14	3rd	M	Biochemistry and pharmacy
Case 15	2 years	M	Biochemistry and pharmacy
Case 16	3.5 years	F	Biochemistry and pharmacy

between scholarship and entrepreneurship by creating a complete chain – from education, research, product development, and production to commercialization. Turku has been a pharmaceutical and diagnostics industrial base for many international companies, such as Leiras (Schering), Wallac (Perkin-Elmer) and Imanet (Amersham/General Electrics), as well as Finnish pharmaceutical companies such as Orion Pharma. This creates good conditions for establishing a platform to bring together academic and industrial scientists and doctoral students.

BioCity Turku comprises about 80 biotechnology companies, six research programmes and 12 graduate schools in the fields of life sciences and medicine. The six research programmes consist of more than 80 research groups with about 1,000 scientists and students. The graduate schools offer national networks, courses, seminars and conferences for doctoral students.

Typology of PhD research collaboration with industry

Four major types of PhD research collaboration with industry were identified from the in-depth interviews carried out in this study, characterized here as *Financial*, *Interactive*, *Kangaroo* and *Appendant*. They differ according to the degree to which they are related to industry. In the first two types, doctoral students are mainly based in universities; the third and fourth types occur in industry. With regard to the literature discussed above, two major aspects of PhD students' experiences were examined: (1) industrial involvement in

supervision and research training; and (2) academic freedom.

The four divisions of PhD research collaboration are not fixed. They can vary according to the evolution of the relationship between academia and industry during the development of a joint project. For example, two of the PhD students interviewed were involved in more than one type of research collaboration: case 4 is a combination of the *Financial* and *Interactive* types and case 9 is a combination of the *Interactive* and *Kangaroo* types.

A – *Financial type*

The *Financial* type of PhD research collaboration has the least direct connection with industry. Collaboration exists only at the funding level. This type is characterized by its external financial support, lack of active participation by industry in the joint project and almost unconstrained academic freedom.

Four of the sixteen PhD students (cases 1, 2, 3 and 4) were involved in this type of research collaboration: two females (2 and 3) and two males (1 and 4). They were variously in years 2–6 of their studies. Case 4, as indicated above, was also associated with the *Interactive* type.

Industrial involvement in supervision and research training. The involvement of industry in this type of research collaboration is mainly in the form of finance and physical resources. In two of the four cases (cases 1 and 2), the research projects were entirely funded by the companies. The other two (3 and 4) were funded by TEKES (the National Technology Agency in Finland). Apart from financial support, industry also provided other resources such as materials or chemicals in three cases (1, 3 and 4) and help with laboratory tests in one (case 2).

One important feature of industrial involvement in this type of collaboration is that university supervisors play an important role in the supervision of the doctoral students. Guidance from university supervisor(s) was perceived as more significant by students than advice from their industrial contact scientists. Doctoral students received advice or feedback from the company through formal meetings or electronic correspondence. Three of the students had one or two industrial contact persons and formal project meetings comprising doctoral students, university academics and industrial contact scientists were held 2–4 times a year either in the company or at the university. Doctoral students usually communicated with their industrial contacts on issues such as requirements for materials or practical laboratory matters. In contrast, they would approach their university supervisors on issues related to research

direction. For the one student who did not have an industrial contact person, a written report was sent to the company about twice a year.

The industrial involvement of industry in the research training programme for doctoral students, for example through seminars, courses, workshops or conferences, was limited in this type of collaboration. The companies did not sponsor doctoral students to attend such events, apart from two cases where part of the expenses for attending a conference was paid by the company; and doctoral students were not invited to give a talk about their work, nor were they involved in any meetings in the company.

Academic freedom. The *Financial* type of PhD research collaboration enjoys the most academic freedom. University academics had complete control over the research design, including research topics, research methods and methods of analysis. The companies did not interfere at any stage of the research, as the following quotes from students illustrate.

‘The research planning is totally free. Actually my research area has been changed quite a lot from the beginning. It is no problem at all.’ (case 1)

‘We have all academic freedom we want. We own the study here. We have the agreement that it is our study, our idea and they are just supporting us financially.’ (case 2)

‘The company does not give any pressure on the timetable or the design of the study. . . . We are able to pursue the research we decided.’ (case 4)

In one case, the research topic was initially suggested by the company, but the company did not interfere with any part of the research.

‘We can do the research in any way we want’ (case 3).

Although doctoral students in this type of research collaboration have academic freedom almost equal to that of their counterparts whose PhD studies had no industrial links, there were some checks on publication and public presentations. All four cases said that they needed to show the company their research findings and that prior to publication or public presentation they were required to send articles to the company first. Three of the four cases (1, 3 and 4) needed to obtain permission from the company before they could publish anything; this was due to patent applications (cases 1 and 3). For case 2, formal consent from the company to publish was not required – the company merely expected to be informed prior to any publication. ‘They just want to

see what the results are earlier, so that they can react to the publication, if it happens to be something that is not so good' (case 2). None of the cases was asked to include anyone from the company to be a co-author of an article written for publication.

Another feature of this type of research collaboration is the lack of a confidentiality agreement. This makes the *Financial* type distinct from other types, especially the *Interactive* type. None of the three typical cases (cases 1, 2 and 3) signed a confidentiality agreement with the company and this helped reduce the impact of the 'secrecy culture', so that the students could engage in a normal academic exchange of ideas. However, case 4 did sign a confidentiality agreement, making it an *Interactive* type – and this is discussed in the next section.

B – Interactive type

The second type, *Interactive*, is characterized by its frequent and close contacts with industry, even though the doctoral students concerned were based at universities. The close contacts with industry entail the active involvement of industry in the supervision of the students, its participation in the research design of the joint project and restricted academic freedom due to the requirements of a confidentiality agreement.

In total, six cases were involved in this type (cases 4–9). Of these, four are typical cases (cases 5, 6, 7 and 8) with five being male students (cases 4–8). They were variously in years 3–5 of their studies. Cases 4 and 9 were also associated with the *Financial* type (case 4) and the *Kangaroo* type (case 9).

Industrial involvement in supervision and research training. In this type of research collaboration, companies provided financial support for the projects, as was the case with the first (*Financial*) type. Three projects (cases 6, 8 and 9) were funded to a significant extent by the companies. The other three were funded by TEKES (cases 4, 5 and 7). As with the first type, industry also provided other resources such as physical materials (cases 4, 6, 7 and 8), new facilities (cases 6, 7, 8 and 9) and laboratory tests (case 8).

Industry played a more important role in the supervision of the PhD students than was the case with the first type. Two of them had a supervisor from industry (cases 6 and 9); all the other cases had industrial collaborators. All the typical cases (apart from case 4, because of its link with the first type) and case 9 stated how important their industrial collaborators or industrial supervisors were. This is manifested in two ways: the significance of the role of industrial collaborators/supervisors in doctoral students' supervision; and the close contact between them. First,

industrial collaborators/supervisors are perceived by the students as being as important as university supervisors, if not more so. The advice from industrial collaborators/supervisors was highly regarded. Two of the students actually indicated that their industrial collaborator (case 5) or industrial supervisor (case 6) played a more significant role than their university supervisors.

'When we think about what to do next, what should we do in the following month and how we can save money, it is mainly decided by the people from the company and me.' (case 7)

Apart from recognition of their expert knowledge, the importance of industrial collaborators/supervisors can be attributed to the fact that the company wanted to be active in the joint project; and this makes it different to the first (*Financial*) type.

In addition to offering guidance, the industrial collaborators/supervisors also served as a means by which the students could access company resources, as this quote illustrates:

'I have more contacts with the industrial supervisor. My industrial supervisor is not the only person who helps me from the company. If I have some questions I turn to her first. Then she tells me who the possible person is that I should contact and ask. She is the person in the company that I contact first.' (case 6).

Furthermore, meetings between industrial collaborators/supervisors and the students were frequent. For some there was daily contact (cases 6 and 7); for others, it was twice a month (case 5) or once every two months (case 8). Frequent – and, it proved, lengthy – formal project meetings, which included industrial collaborators/supervisors, university supervisors and students, were also held, about 5 or 6 times a year, such meetings lasting one to two days.

As with the *Financial* type, the involvement of industry in the research training of the doctoral students was limited. The companies did not offer any training courses, seminars or conferences, neither did they directly sponsor students to attend any such events. The only exception was case 7, where the company actively supported the research training of PhD students.

Academic freedom. Academic freedom in the *Interactive* type of collaboration is restricted, because of the demands of the confidentiality agreement. Four typical cases and the two mixed cases all signed such agreements, arising from which there were direct consequences with regard to: (1) active participation of industry in joint projects; (2) constraints on exchange

of ideas; and (3) publication, which will be discussed here.

As well as providing financial support, companies played an active role in joint projects, being engaged in research design and in making joint decisions with university academics and doctoral students with regard to the direction of research for the project. Feedback from industry was given serious consideration.

‘For the design of the research, it is pretty much that they [the company] decide what the primary interest for them is at that time. Their interest can change even after a few months.’ (case 7)

‘I would say they [the company] are very much involved [in the research project]. We have meetings with the company every 3 months . . . We discuss what we should do next, such as how to continue the project.’ (case 8)

In one instance (case 6) the design of the research was decided entirely by the company. This included the research topic, research plan and deadlines for the doctoral student.

The next issue was that, because of company interests with regard to potential patents and new products, doctoral students in all six cases stated that they could not freely discuss their ideas with others, nor could they discuss anything related to a product or reveal any information from the joint projects. Such a state of affairs can jeopardize the free exchange of ideas for doctoral students in academia and it can also hinder normal academic discussion. One of the students described how this influenced his attendance at the conferences.

‘Actually they [the company] are afraid if I go to conferences and present some things myself. They are afraid if I tell something that they don’t want others to know . . . Another reason the company is not happy to see me to attend the conferences is that even if it is a short abstract in a conference, the company is afraid you said something which has a potential to be patented later.’ (case 7)

In another example, the doctoral student was not allowed to tell anyone about the topic of his research for two years:

‘If somebody asked me: what is the topic of your research? I could just say ‘top secret’ or something like that. I couldn’t tell anything else. It would reveal everything if I tell the topic’ (case 6).

He was not permitted to answer any questions related to his research. This also affected his attendance at the

conferences: he was not allowed to attend any conference or seminar for two years. He pointed out that as a result he missed many opportunities to exchange ideas with scientists from his field and to network with others in his field.

The secrecy culture can also cause problems in interpersonal relationships for doctoral students and it can undermine the trust that exists between professionals.

‘It [the culture of secrecy] can influence my personal relationships in the department. And then you don’t get to know people so well’ (case 6).

Secrecy can also be an issue in communications with people from the company.

‘I get a lot of information from them [the company], but sometimes I have a feeling that they are not telling everything because they want to keep something secret. For example, sometimes when we find something, they say “Yes, we have noticed the same thing”. They do not directly tell us specific things. It is not only me who has worked with this company that notice this.’ (case 7)

The secrecy culture naturally results in constraints on publication. As with the *Financial* type, doctoral students would need to have approval from the company before publishing anything but, in contrast to the first type, the process for obtaining approval is stricter, more complicated and takes longer. Usually, an article intended for publication would need at least two major approvals in the company, one from the head of the department in which the joint project is based and the other from the patent department (or similar). Other forms of publication constraints included the prohibition of any publication and any attendance at conferences/seminars for the first two years (case 6); a PhD thesis published as a monograph only, with limited access (cases 6 and 7); and the requirement for inclusion of industrial collaborators as co-authors (case 8).

As a consequence, doctoral students’ studies can be prolonged. The approval and patenting processes in a company can delay publication for months, or even years. The constraints on publication and on academic freedom can result in doctoral studies taking longer to complete in comparison with those of counterparts not involved in a joint project with industry.

C – Kangaroo type

In both the *Kangaroo* and *Appendant* types, doctoral students are based in the companies. The *Kangaroo* type is characterized by the way that the research project

relates to the company's normal operation: PhD students are paid by the company and carry out their doctoral projects full-time in the company, with few other formal company obligations. The 'kangaroo' analogy is used because the way that a company supports a PhD students' project is similar to that of a mother kangaroo carrying her babies in her pouch.

Five typical cases (10, 11, 12, 13 and 14) were found to be involved in this type of research collaboration. Case 9 was also associated with this type. The six consisted of 3 female students (cases 9, 10 and 13) and 3 male students (cases 11, 12 and 14), with students variously in years 1–5 of their studies. Cases 13 and 14 worked in a not-for-profit company, CSC, owned by the Finnish Ministry of Education.

Industrial involvement in supervision and research training. The companies were actively involved in almost all aspects of the research projects. With regard to funding, the companies paid not only the research expenses but also the salaries of the doctoral students: all of the students were full-time employees. Companies also provided all the necessary materials and facilities for the PhD projects – which were also company projects. The only exception was case 13: although this student worked full-time in the not-for-profit government company, she was sponsored by her graduate school.

With regard to supervision, although the students were affiliated with an academic department and therefore had university academics as their supervisors, they were more closely involved with their industry supervisors. As well as their university supervisors, all six had one to three industrial supervisors.

One common feature was the fact that all the industry supervisors played a more important role in the supervision of the doctoral students than university supervisors. The industry supervisors assumed primary responsibility for the progress of their students: for example, the students met their industry supervisors on a daily basis, while in contrast they met their university supervisors only one to three times a year.

The companies also provided some support for research training, but this provision could vary. Most of them organized internal talks or courses that doctoral students could attend (cases 10, 12, 13, 14 and 9). For external events, in three cases (10, 11 and 12) students were allowed to attend external seminars or courses, but this was not an easy procedure. First, it depended on the financial situation of the company. The companies at one time adopted an encouraging attitude towards the participation of their doctoral students in external training courses or seminars; but, due to negative changes in the economic climate, mostly after 2000,

companies became more conservative and less likely to support their students to attend such activities. For example, because of changes to the company's financial situation, case 11 was only allowed to attend courses in his own time. In addition, time spent on external training needed to be justified and would only be accepted if it was expected to be beneficial for the company.

'We [in the company] always have to do a travel request and have to explain why we want to go and what we can bring to the company. We cannot just say that it is interesting for my PhD. If there is something, for example, that is interesting for you personally but not clear to the company, usually you don't get to go there.' (case 10)

The only exception is case 13 (in the not-for-profit company and sponsored by her graduate school) where the student was free to attend any seminar or courses in the university.

Academic freedom. Academic freedom in the *Kangaroo* type of PhD research collaboration was very limited, due to the fact that the students' projects were also company projects. The companies therefore exercised significant influence or exerted strong control on almost every aspect of student projects – from choice of research topic and research methods to research design. Students had to meet the business goals of the company and they had very limited freedom to explore related issues or to follow up interesting findings. Company permission was needed if they wished to proceed to the next stage or try anything different.

'The company influences my research a lot because my research has to be something that the company is interested in.' (case 11)

'I would say I don't have academic freedom in a company. In a company, it must work in this way: if you study articles and you find something or have an idea, you still need to go through your boss in order to let you carry on. In the university, you can try something on your own. . . . It is part of a company project. I cannot do my own research for my own needs. It is more restricted because the company doesn't want to spend money.' (case 10)

All students signed a confidentiality agreement. As with the *Interactive* type, this imposed constraints on the exchange of ideas and publication. Students were required to obtain company permission before entering into discussions with others. As one said, 'whatever subjects I talk about, I have to discuss with the company

beforehand' (case 11). It was openly admitted by the students that this can create problems for scientific freedom.

Publication of the work of doctoral students was also delayed. The main reasons, similar to the *Interactive* type, were the need to accommodate internal approval and patenting procedures and processes.

'I am not sure there is that kind of thing [academic freedom] here. Hypothetically if our technology does work on something, I cannot publish it. In this sense, there is no freedom. I have to have permission from the company to publish things.' (case 11)

'At the moment, I cannot publish. Using the company data constrains my publication. It will not only cause the delay in my publication but also some of my findings will never get published.' (case 14)

As with the *Interactive* type, publication could be delayed for months, even years. This constraint on publication not only impedes the students' intentions and need to publish their work but also creates risks for their study. One important criterion for a doctoral thesis lies in the original nature of its contribution to the field. The constraint on publication arising from commercial sensitivities and requirements can effectively degrade the originality of the work by preventing the timely publication of novel results and inhibiting the exploration of new areas. For example, as one of the doctoral students pointed out:

'One of the major risks is that if you find something novel, it may not be published, because it is too valuable to be published. That, of course, is a major risk if you think of a PhD. Others are the delay of publication and also the restrictions for you to explore new areas. . . . The major risk is that you may have the material but you are not allowed to publish it. I think that is a tough risk.' (case 10)

The restriction of academic freedom, especially with regard to publication, can therefore cause problems for doctoral students working in this type of research collaboration.

D – Appendant type

Although there are fewer cases than in the other types, it is worth reporting this *Appendant* type because of its particular features and special significance. Doctoral students in this type had a unique experience of research training because the *Appendant* type of PhD research collaboration was characterized by its subsidiary nature and high risk. As with the *Kangaroo* type, doctoral students were based in industry. However, rather than

being cherished in the 'mother company's pouch', as in the *Kangaroo* type, student projects in the *Appendant* type were perceived as supplementary works existing alongside other research work in the company. Thus they were attached to or greatly dependent upon other, principal company activities.

Companies in this type also provided resources and supervision, but the students had to face greater uncertainty and therefore bear more risks than those in the *Kangaroo* type, because their PhD projects were subsidiary, subordinate and additional to those of the company. If the company decided to change its research direction and terminate a research project, the doctoral students could do nothing other than abandon their PhD projects or start afresh on a different topic.

Two cases (case 15, a male student and 16, a female student) were engaged in this type of research collaboration. Unfortunately for this present research, both cases stopped their PhD studies, after two (case 16) and three and half years of study (case 15) and both for the same reason – they moved away from their companies.

Industrial involvement in supervision and research training. As was the case with the *Kangaroo* type, companies were significantly involved in almost all aspects of the doctoral students' projects. They took charge of supervision and offered resources for the work. The students were full-time employees and were paid a salary by the company.

However, what makes the *Appendant* type distinctive is that the PhD projects were perceived as less important for the company than was the case for those in the *Kangaroo* type. The students did their PhD work alongside other company activities and so doctoral projects which did not play a significant role – from the company's point of view – were marginalized. The projects did not attract much attention from the company and as a result the 'other company engagements' of the students – company projects – received more attention than their own 'sideways' PhD work. For example, the student of case 16 was allowed only 20% of her working time to do PhD work – one day in a week. Both *Appendant* type students indicated that their PhD studies had been easily distracted by other company work.

'Some company-related projects can be so important that you have to leave your PhD project aside for many months. You have to concentrate on the projects which are important for the company.' (case 15)

'At that time, the company was growing. We were trying to get finances, go further with projects and

also my input was more needed in another project than the one was given to me as my PhD project. . . . Although it [the PhD project] was suggested to me and I was doing it, there was still no time for that because it was less important for the company.’ (case 16)

If this is the case, the question then becomes: why did they not choose a topic which was more important to the company for their PhD? In both cases, the answer lies in the issue of confidentiality with regard to publication. It was not easy to find projects in the company that could eventually be published.

‘The company could give me a more important project, because those projects are secrets. They are the development projects which cannot be published. For a PhD, of course, publishing things is important. This is what makes the whole situation difficult from the beginning.’ (case 16)

‘This is how the topic was chosen: to give me something which was not that critical, which could be published and therefore is also less important for the company.’ (case 15)

On the other hand, companies in the *Appendant* type of research collaboration were more willing to support the research training of their doctoral students than those in the *Kangaroo* type. Companies in both cases offered support for the students to attend conferences and workshops abroad, training courses at universities, internal training courses in the company and internal meetings in the company group. Both of the students were allowed to participate in these activities during their work time and all the activities were paid for by the companies unless the students had been invited to attend, and were therefore paid for, by the organizers.

Academic freedom. The students also had to sign a confidentiality agreement and, as with the other types, this resulted in some constraints on publication. Company permission was required prior to any publication; publication might also be delayed because of patent applications and approvals.

‘The secrecy makes publishing become an issue. It is very strict. All the information that goes outside is carefully controlled’ (case 16).

The companies exercised significant influence on the research topic, methods, tools and design of the students’ projects.

‘The direction of the project and the research area are decided by the company. I couldn’t select whatever I

want. It has to be something which is related to what the company does.’ (case 15)

Although academic freedom in the *Appendant* type is restricted, it seems to enjoy a slightly better situation than that in the *Kangaroo* type or, sometimes, better even than that in the *Interactive* type, especially in terms of exchange of ideas. This is because the companies in the *Appendant* type took the secrecy issue into account at the commencement of the PhD projects. For example, the student in case 16 did not think that the requirement for secrecy influenced the academic discussion to any significant extent, ‘because, as we said, the project was already carefully chosen. It is such a project which you can discuss.’ In contrast, the student in case 15 found that the secrecy caused by the terms of the confidentiality agreement made the PhD study complicated and difficult. It was not possible for him to discuss relevant matters freely with others. Such a situation can impede a student’s research progress.

Discussion

These four types of PhD research collaboration are discussed in the context of the knowledge dispositions elaborated earlier. In connection with its two dimensions, academic freedom and open science, the four types of PhD research collaboration are presented in Figure 2. The *Financial* type, characterized by its external financial support, inactive industrial participation of the joint project and almost unconstrained academic freedom, is located in the first quadrant. The *Kangaroo* type, characterized by how doctoral students’ research projects ‘parasitize’ the company, the active industrial participation of the joint project and very limited academic freedom, is situated in the third quadrant, almost exactly opposite the *Financial* type. Equally, the *Appendant* type, where

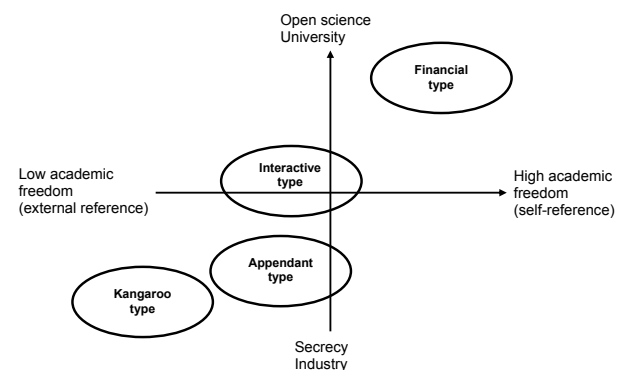


Figure 2. Framework for the four types of PhD research collaboration.

doctoral projects were perceived as supplementary and additional to other research work in the company, but in which industry is seen to be more aware of academic freedom and the importance of research training than the *Kangaroo* type, is positioned to the right of the *Kangaroo* type. Finally, the *Interactive* type, characterized by its active industrial involvement in supervision, industrial participation in research design and constrained academic freedom due to the terms of the confidentiality agreement, is located in the middle of the diagram.

The different dispositions of knowledge – expert, utilitarian and commercialized – held by academia and industry manifest themselves in the four types of PhD research collaboration. The first two types, *Financial* and *Interactive*, are based in universities. The important role played by the university supervisors in these two types reflects university-oriented knowledge dispositions – the dispositions of legitimate expert knowledge and utilitarian knowledge. The first type, *Financial*, characterized by the least industrial involvement in supervision and research training and the greatest autonomy for research design, demonstrates best the legitimate expert knowledge disposition. Its almost unconstrained academic freedom illustrates its efforts to distance itself from societal and economic values and to continue to be the independent critic of society (Krimsky, 1991). In this instance, doctoral students are trained to be scientists who can inherit the legitimate expert knowledge disposition in the university.

The *Interactive* type – characterized by, first, its university base and university supervision; next, its reciprocal communication between university and industry; and finally its constrained academic freedom – is seen to signify best the utilitarian knowledge disposition. Its interactive relationship with industry shows its social and instrumental intentions (Ziman, 2003) and its interventionist approach. However, academic freedom is compromised, especially with regard to publication and exchange of ideas. Doctoral students in this instance are perceived as missionaries at the frontier of the utilitarian knowledge (Slaughter *et al.*, 2002).

In contrast, the *Kangaroo* and *Appendant* types are based in industry. The significant role played by the industrial supervisors in these two types corresponds well to the industrial-oriented knowledge disposition – commercialized knowledge. In order to protect its commercial interests and ensure its competitiveness in the market, it emphasizes secrecy and end products (Zucker *et al.*, 2002): this explains why academic freedom is significantly restricted in these two types, in contrast to the open science (Cohen *et al.*, 2002) shared

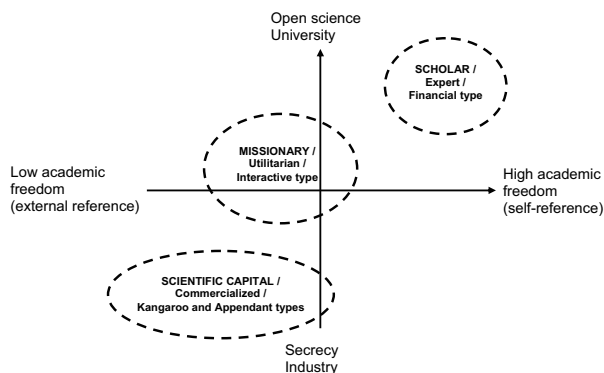


Figure 3. Roles of PhD students.

by legitimate expert and utilitarian knowledge. In both *Kangaroo* and *Appendant* types, doctoral students had to accept restrictions on publication and the exchange of ideas and this hindered the students' progress. In these cases, doctoral students were perceived as valuable social and scientific capital for creating profits for the company.

The different types of roles played by doctoral students in relation to knowledge dispositions and the typology of research collaboration are presented in Figure 3. Two issues are of particular interest. First, despite the involvement of industry, traditional research training is seen to be preserved in the *Financial* type. Doctoral students in this type are trained to be 'normal' academic scholars and this corresponds to the expert knowledge disposition. Next, the research collaboration with industry provides at least two distinct features for research training – its missionary and scientific capital intentions. In other words, in contrast to traditional research training, which stresses the pure pursuit of legitimate knowledge, research training in joint projects with industry can have pragmatic purposes or even be profit-oriented. The former is reflected in the *Interactive* type, with the utilitarian disposition; the latter is manifested in both *Kangaroo* and *Appendant* types, with the commercialized disposition. This raises questions about the nature of research training in collaborative research. What do the distinct features of research training in university–industry collaborations mean? What is the nature of research training in such collaboration? Does it have different purposes? How could doctoral students be supported in such research training?

No significant patterns relating to the gender of the doctoral students or their years of study were found in this research. Both genders are equally represented in three of the four types – *Financial*, *Kangaroo* and *Appendant*. A similar situation was also found in terms of years of study. There were more male than female

students, five out of six, in the *Interactive* type, possibly because half of the cases in this type are based in the industrial chemistry sector and all of these were male students. However, it must be remembered that information on the four major types of PhD research collaboration identified here was mainly derived from in-depth interviews with limited numbers of doctoral students involved in the qualitative study. As a result, there is insufficient data to investigate fully the influence of specific academic subjects in the field of life sciences on the types of relationship between the university and industry. More research is therefore needed in order to study further the possible influences of gender, years of study and academic field on research training in university–industry collaborations.

Conclusions and research implications

The four types of PhD research collaboration, which represent different dispositions of knowledge, give rise to dissimilar research training for doctoral students. The experiences of the students studied vary in two major aspects: industrial involvement in supervision and research training; and academic freedom. Their experiences can also vary according to where they are based – university or industry. In the two types that are based in university – *Financial* and *Interactive* – legitimate expert knowledge and utilitarian knowledge, which stress open science, are manifested. In contrast, in the *Kangaroo* and *Appendant* types, based in companies, it is the industry's commercialized knowledge that is emphasized. It was found that such a disposition can impose serious constraints on the publication of doctoral students' work and the exchange of ideas.

From the discussion and conclusions, I would like to propose two important points which, I suggest, call for immediate attention in this field. First, the research training dimension in collaborative research between university and industry deserves serious consideration and support, from both sides. The constraints and difficulties faced by doctoral students involved in such research should be recognized at the outset. The research training dimension of university–industry collaboration should be officially acknowledged in the research contract signed by both parties. This is especially important for doctoral students based in industry – the *Kangaroo* and *Appendant* types. Universities should take a proactive role in ensuring that PhD students' projects receive satisfactory attention in industry, especially those in the *Appendant* type. This could be achieved by, for example, clearly stating, in the contracts signed by the university and industry before the collaboration commences, the quality

requirements for the supervision, by industry or jointly with the university, of the students.

The second important area that requires further reflection is the nature of research training in collaborative research. From the findings of this present study it is clear that the progress of doctoral students and recognition of their scientific contribution in university–industry collaborative research can become causes for serious concern. The different types of PhD research collaboration with industry indicate that doctoral studies in such research can be delayed or impeded because of restrictions placed on publication or the exchange of ideas. This raises important questions:

- what is the nature of doctoral studies in university–industry collaborative research?
- how applicable and appropriate are evaluative criteria used for doctoral theses not involved in collaborative research with industry to those which are involved in such research?
- what are the appropriate ways for recognizing the contribution of doctoral students in such collaborative research? and
- apart from the traditional route of publications, are there other ways to help students make progress in their doctoral studies?

It is therefore important for both academia and industry to reflect first on current practices, especially with regard to research training in collaborative research; and, second, to find ways to recognize the scientific contribution of doctoral students and to facilitate some measure of exchange of ideas which takes into account the commercial implications of their projects. For example, the closed examination system of PhD theses used in universities in the UK could be helpful for doctoral students involved in collaborative research with industry and whose PhD projects have commercial value. This system would be especially beneficial for those doctoral studies in collaborative research elsewhere in Europe and for which, in most cases, the PhD viva examination is currently an open ceremony and can thus be problematic with regard to issues of commercial confidentiality.

Notes

¹Biocenter Finland is an umbrella organisation of biocenters in six Finnish Universities (Helsinki, Kuopio, Oulu, Tampere and Turku, and the Åbo Akademi University). When established in the 1980's and 1990's, Finnish biocenters represented new types of multidisciplinary research organizations bringing together life scientists and biomedical researchers working in universities, research institutions, hospitals and industry. Establishment of biocenters marked the first stage in the restructuring of basic research; multidisciplinary research programs were initiated, research infrastructure was strengthened through joint core facilities, and researcher training

and technology transfer were reorganized. Biocenter Finland also supports emerging technologies, and promotes international researcher training and recruitment, research career development, and commercial exploitation of research results.' (see also <http://www.biocenter.fi/index.php?page=about-biocenter-finland>, accessed 18 February 2011).

²See: <http://www.biocity.turku.fi/index.php?id=861>.

References

- Barr, N. (2004), 'Higher education funding', *Oxford Review of Economic Policy*, Vol 20, No 2, pp 264–283.
- Behrens, T.R., and Gray, D.O. (2001), 'Unintended consequences of cooperative research: impact of industry sponsorship on climate for academic freedom and other graduate student outcomes', *Research Policy*, Vol 30, pp 179–199.
- Blumenthal, D. (2003), 'Academic–industrial relationships in the life sciences', *The New England Journal of Medicine*, Vol 349, No 25, pp 2452–2459.
- Boyd, E.A., and Bero, L.A. (2000), 'Assessing faculty financial relationships with industry: a case study', *JAMA*, Vol 284, No 17, pp 2209–2214.
- Cohen, W.M., Nelson, R.R., and Walsh, J. (2002), 'Links and impacts: the influence of public research on industrial R&D', *Management Science*, Vol 48, No 1, pp 1–23.
- Crespo, M., and Dridi, H. (2007), 'Intensification of university–industry relationships and its impact on academic research', *Higher Education*, Vol 54, pp 61–84.
- De Bondt, R. (1997), 'Spillovers and innovative activities', *International Journal of Industrial Organization*, Vol 15, No 1, pp 1–28.
- D'Este, P., and Patel, P. (2007), 'University–industry linkages in the UK: what are the factors underlying the variety of interactions with industry?', *Research Policy*, Vol 36, pp 1295–1313.
- Edquist, C. (1997), 'Systems of innovation approaches – their emergence and characteristics', in Edquist, C., ed, *Systems of Innovation: Technologies, Institutions and Organizations*, Pinter, London.
- Enders, J. (2002), 'Serving many masters: the PhD on the labour market, the everlasting need of inequality, and the premature death of Humboldt', *Higher Education*, Vol 44, pp 493–517.
- Evans, G.R., and Packham, D.E. (2003), 'Ethical issues at the university–industry interface: a way forward?', *Science and Engineering Ethics*, Vol 9, No 1, pp 3–16.
- Geuna, A., and Muscio, A. (2009), 'The governance of university knowledge transfer: a critical review of the literature', *Minerva*, Vol 47, pp 93–114.
- Gibbons, M. (2000), 'Mode 2 society and the emergence of context-sensitive science', *Science and Public Policy*, Vol 27, No 3, pp 159–163.
- Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., and Trow, M. (1994), *The New Production of Knowledge: the Dynamics of Science and Research in Contemporary Societies*, Sage, London.
- Glaser, B.E., and Bero, L.A. (2005), 'Attitudes of academic and clinical researchers toward financial ties in research: a systematic review', *Science and Engineering Ethics*, Vol 11, No 4, pp 553–573.
- Granovetter, M. (1985), 'Economic action and social structure: the problem of embeddedness', *American Journal of Sociology*, Vol 91, No 3, pp 481–510.
- Harrison, G.P., Macpherson, E.D., and Williams, D.A. (2007), 'Promoting interdisciplinarity in engineering teaching', *European Journal of Engineering Education*, Vol 32, No 3, pp 285–293.
- Krimsky, S. (2004), 'The temptations of corporate funding', *Trusteeship Magazine*, Vol 12, No 2, March–April.
- Krimsky, S., Ennis, J.G., and Weissman, R. (1991), 'Academic–corporate ties in biotechnology: a quantitative study', *Science, Technology and Human Values*, Vol 16, No 3, pp 275–287.
- Kyvik, S., and Olsen, T.B. (2008), 'Does the aging of tenured academic staff affect the research performance of universities?', *Scientometrics*, Vol 76, No 3, pp 439–455.
- Lambert, R. (2003), *Lambert Review of Business–University Collaboration*, HMSO, Norwich.
- Liebeskind, J.P., Oliver, A.L., Zucker, L., and Brewer, M. (1996), 'Social networks, learning and flexibility: sourcing scientific knowledge in new biotechnology firms', *Organization Science*, Vol 7, No 4, pp 428–443.
- Lynskey, M.J. (2010), 'Capitalizing on knowledge from public research institutions: indications from new technology-based firms in Japan', *Industry and Higher Education*, Vol 24, No 1, pp 29–45.
- Martin, M. (2000), *Managing University–Industry Relations: a Study of Institutional Practices from 12 Different Countries*, International Institute for Educational Planning, Paris.
- Mendoza, P., and Berger, J.B. (2008), 'Academic capitalism and academic culture: a case study', *Education Policy Analysis Archives*, Vol 16, No 23, pp 1–24.
- Meredith, S., and Burkle, M. (2008), 'Building bridges between university and industry: theory and practice', *Education and Training*, Vol 50, No 3, pp 199–215.
- Merton, R.K. (1968), *Social Theory and Social Structure*, The Free Press, New York.
- OECD (2008), *OECD Science, Technology and R&D Statistics* (on CD-ROM), OECD, Paris.
- OECD (2009), *OECD Interactive Charts*, OECD, Paris, <http://webnet.oecd.org/nawwe/factbook09/default.html>, accessed 16 September 2009.
- Olivieri, N.F. (2003), 'Patients' health or company profits? – the commercialisation of academic research', *Science and Engineering Ethics*, Vol 9, No 1, pp 29–41.
- Prigge, G.W. (2005), 'University–industry partnerships: what do they mean to universities? – a review of the literature', *Industry and Higher Education*, Vol 19, No 3, pp 221–229.
- Pritchard, M.S. (1996), 'Conflicts of interest: conceptual and normative issues', *Academic Medicine*, Vol 71, No 12, pp 1305–1313.
- Slaughter, S., Campbell, T., Holleman, M., and Margan, E. (2002), 'The 'traffic' in graduate students: graduate students as tokens of exchange between academe and industry', *Science, Technology and Human Values*, Vol 27, No 2, pp 282–312.
- Slaughter, S., and Rhoades, G. (2004), *Academic Capitalism and the New Economy: Markets, State and Higher Education*, Johns Hopkins University Press, Baltimore, MD.
- Thomas, S., and Busby, S. (2003), 'Do industry collaborative projects enhance students' learning?', *Education and Training*, Vol 45, No 4, pp 226–235.
- Thune, T. (2009a), 'Doctoral students on the university–industry interface: a review of literature', *Higher Education*, Vol 58, No 5, pp 637–651.
- Thune, T. (2009b), 'Proximity and interactive learning in university–firm relationships', *Industry and Higher Education*, Vol 23, No 1, pp 7–16.
- Times Higher Education (2009), 'Freedom fighters "when it suits"', *Times Higher Education Supplement*, 28 May.
- Vest, C.M. (2006), 'Industry, philanthropy, and universities: the roles and influences of the private sector in higher education', *CSHE Research and Occasional Paper Series*, University of California, Berkeley, CA.
- Veugelers, R., and Cassiman, B. (2005), 'R&D cooperation between firms and universities: some empirical evidence from Belgian manufacturing', *International Journal of Industrial Organization*, Vol 23, pp 355–379.

Vinding, A.L. (2004), 'Interaction between firms and knowledge institutions', in Christensen, J.L. and Lundvall, B.-A., eds, *Product Innovation, Interactive Learning and Economic Performance*, Volume 8, Elsevier, Oxford.

Weatherall, D. (2003), 'Problems for biomedical research at the academia-industrial interface', *Science and Engineering Ethics*, Vol 9, No 1, pp 43–48.

Ziman, J. (2003), 'Non-instrumental roles of science', *Science and Engineering Ethics*, Vol 9, No 1, pp 17–27.

Zucker, L.G., Darby, M.R., and Armstrong, J.S. (2002), 'Commercializing knowledge: university science, knowledge capture and firm performance in biotechnology', *Management Science*, Vol 48, pp 138–153.